

Meet Your New Riding Tool

The Power Meter

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Power meters for cycling are relatively new. It's not simple to precisely capture the transfer of energy from your body to the bike—that is, your power—while withstanding impact forces from rough road surfaces and the effects of rain and humidity, dirt and grime. And it isn't easy to insert strain gauges into the center hub of your rear wheel—gauges that are so sensitive that they can measure changes in the strain on the very metal of your hub. Sensing the twist or torque, and converting that twisting deflection into a power reading, is a surprisingly delicate process.

**A PowerTap
power meter hub.
Strain gauges are
implanted on the
inside of the hub.**



Similarly, it's not easy for a rider new to power meters to understand what that power reading—your effort in watts—means. But getting to know how a power meter measures your effort is worth the education and saddle time, because it's knowledge that will directly help you manage your training.

According to Allen Lim, Ph D., Director of Cycling Science at the CycleOps division of Madison-based Saris Cycling Group, "Power is a measurement of intensity. Just like a thermometer inserted into a

turkey that is cooking in your oven—the power meter is the thermometer inserted into your riding experience that measures your riding intensity."



Why does the intensity or “heat” of your ride matter? Well, if you’re riding above your optimum intensity, you’re going to overcook and under perform. If you are riding at too low an intensity, with an overly cool effort, you aren’t going to gain the training

benefits that you want to achieve. A power meter helps you to quantify your training and *optimize* it, so you can accurately follow your training recipe and cook the perfect turkey, so to speak.

What a power meter actually measures is the amount of energy that you are applying onto your pedals every second—with the result given in watts, a unit of energy. But that’s more a definition of power than an explanation. To explain power, it may be better to start with what power is not.

Power and **speed** (a better term is “**velocity**”) are related, but they aren’t the same thing. Speed is how fast you are riding, and it is the result of many variables: terrain or grade, road surfaces, wind resistance, body position on the bike, aerodynamics, *and* your power. But power is simply how hard you are riding, and for any given distance of ride it’s only affected by two variables:

1. How hard you are pushing on the pedals (**force**).
2. How fast you are pedaling—your cadence or “RPM” (but for purposes of this would-be physics lesson, we’ll be looking not at your RPMs, but at the speed or **velocity** at which your bike is traveling, broken up into its **distance** traveled over a given amount of **time**).

There are several different manufacturers of power meters that use different methods of measuring this energy. The best way of measuring power, the CycleOps PowerTap way, is to use strain gauges mounted in the hub of the rear wheel. Strain gauges measure the stretch on the metal parts, called **torque**, as force is applied to the metal when you push on the pedals. The power meter uses these torque

measurements to compute your power in watts, which it displays on a meter that's mounted on your bike's handlebars. Of course, while torque is a key concept from the perspective of the power meter and the bike, it's more helpful for you and I to understand what is happening on the human end.

For a rider, **power** is the rate at which you work—the amount of **work** you've done, divided up over the amount of **time** you've been working.

And what is “work” other than what you do in your job or around the house? **Work** in the mechanical sense is your total effort in applying **force** (torque, in this case) across a given **distance**.

So, to generate the most power when you are riding, you must pedal at the highest gear that you can push (applying the greatest torque or force) for a given distance. Then, to give a value to that power:

you take your force,

multiply it by the distance you've traveled,

then divide it by how long it took you to go that distance.

What you get as a result is watts, a lovely, concise value to encapsulate, compare, and optimize your training, for the purposes of fun, health, and victory! To recap, here's the power formula:

$$(1) \text{ Power} = \frac{\text{Work}}{\text{Time}}$$

$$(2) \text{ Work} = \text{force} \times \text{distance}$$

Therefore

$$(3) \text{ Power} = \text{force} \times \text{distance} / \text{time}$$

Understanding Power Output Information

Term	Formula	Description	Units
Work:	Force x Distance	The total effort you've spent in applying force across a given distance.	Kilojoules
Power:	$\frac{\text{Work}}{\text{Time}}$	The work you've done, divided up over the amount of time that you've being working.	Watts

Power meters are the preferred training tool of competitive cyclists because they measure exactly what they need to know—work over time. The rider that can work the hardest, for the longest period of time, wins the race. Regardless of the cardiac cost (heart rate) or the GPS location (way point), power meters are essential tools for today's rider.



Here's an example. Say that you are riding for just 30 seconds, and your power meter reads 100 watts. The 100 watts is the rate of work that you are doing on the bike during those 30 seconds. If you want to double your power output but keep the amount of work the same then you can ride at 200 watts but only for half the time, 15 seconds.

Here's another example to help clarify the power of riding with power. Riding up a favorite hill always requires a certain amount of power. When you ride up your favorite hill faster, you are producing more power. That's because you are producing more work at a higher rate. If you ride up your favorite hill more slowly, you still get to the top, but your power meter will display a lower number, because it has taken you a greater amount of time.

Consider it another way; you love to ride the last 3 minutes of your training ride faster and harder. You have been riding most of the steady state ride at 175 watts. This is in your heart rate Zone 3, 70%-80% of your maximum heart rate. But, for this last three minutes you want to step on it, do a long pick up, and increase your power by as much as you can for three minutes. While doing so, you note that this increase is 25 watts per minute, and the last three minutes of the ride you average 200 watts of power. Two weeks later you repeat the same ride, and the other conditions remain the same—same course, same weather, same distance, same bike, and same time of day. You now average 210 watts per minute for the last three minutes. You produced more power at 210 watts than at 200 watts, and this should result in riding faster (all outside variables remaining the same) and a faster finishing time.

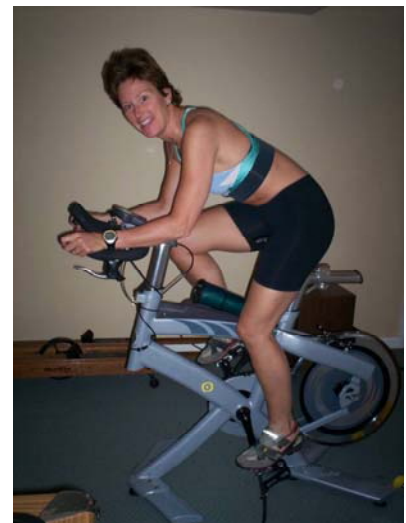
The number of watts that your meter displays during a ride may fluctuate a lot. At first you may think, “Oh my. I can’t get this watts number to stay the same. It just bounces from 165 to 93 to 180, and I’m hardly doing anything to make this happen.” Wattage does fluctuate rapidly and frequently during the ride; it’s a jumpy number, and this is normal. Power meters are very sensitive to the slightest change in pedal pushing or pedal speed (RPMs). Because of this jumpiness of the watt number, I recommend that you look at all of the data displayed on your power meter dashboard—speed/velocity, cadence, heart rate, and, most of all, watts—to reassure you that your efforts are being rewarded.

Most power meters have the capability to store all of the dashboard data. After the ride, you have two choices—look at it on the dashboard from the summary mode or dump the data into your computer or PDA and let the companion software analyze it for you. I recommend both. The former is immediate feedback and rewards your effort at the moment, and the latter is essential for keeping a log or record of your rides.

Want to improve your power on the bike? Well, rest assured, so does everyone else using their new power meter. This is one of the best reasons to ride with one. Just like the cook that prepared the perfect turkey, power improvements are a combination of art and science, using a ride program based on power meter training that gets you that result—more power per minute of riding at the same energy cost.

I’ve got a few quick tips to get you started with improving your power output numbers on the bike. Strength training using hill workouts and cadence drills can help to improve your power ability pretty quickly. And do remember that since there are only three different ways to increase your power output on the bike, focusing on each one individually can get you some impressive improvement as well:

Kathy Kent, Heart Zones Master Trainer, riding a Cycleops 300 PT



1. Increase your cadence.
2. Increase the gear.
3. Push harder on the pedals, apply more force.

The Two Sides of Measurement: Direct and Indirect

There are two sides to every coin and measuring your training effort is no different. On one side of the coin is the direct, external force that you are applying over time onto the pedal, your power. On the other side of the coin is something more indirect and quite internal, but equally useful in managing your training. It's an overview of your body's internal efforts at a moment in time: your heart rate. Together, measuring both the external and internal, direct and indirect aspects of your efforts will give you the truest picture of the results of your training.

Say you take off for your morning ride, and as you warm-up the power meter averages a reading of about 125 watts. At the same time, your heart rate number reads 110 bpm. The next morning, you do your warm-up riding at the same speed over same course. Your power meter reading should again average about 125 watts. However, your heart rate might easily be 125 bpm. Or 95 bpm. This is because power is a direct measurement of work, but heart rate is an indirect measurement that also gives you a reading on your entire physiology—including the effects of how much sleep you had the night before, whether you ate breakfast, if you are under-rested from the ride the day before, and so much more.

Heart rate is valuable exactly because, for an equal amount of external effort, these internal readings can be quite variable. If we were machines, not human athletes, we wouldn't need to be aware of any indirect variables in managing our performance. To excel and win, increasing our power alone would be enough. But because our power depends on the performance of our bodies, and because all

aspects of our bodies are *not* under our direct observation and control, heart rate gives us priceless internal feedback.





Using data, especially data that compares power intensity with heart rate intensity to assess training improvements over time, is a key way to monitor your cycling improvements. If your cycle plan, your recipe, is working, you'll see the ratio of power in watts to heart rate in beats per minute improve. Want a tank full of confidence? There's no better way than to see this type of hard evidence that you are fitter, stronger, and faster on the bike. "Through the use of a heart rate-power system, you will see significant improvement in race performance when you begin training with power. Applying each of these intensity monitoring systems has the potential to dramatically improve training and racing," writes Ed Burke in his book titled *Serious Cycling*.




The simplest way to use your power in watts and your heart rate in bpm together is to observe their relationship while doing the same ride at different times:

- If you are riding at the same heart rate but at a higher power output, your cycle fitness is improving.
- If you are riding at the same power output, but at a lower heart rate, your fitness is improving.

What you don't want to see happen is doing the same ride at the same heart rate but at a lower power output. This would mean that your cycle fitness is declining, and your training plan is not working for you. Similarly, if you do the same ride at the same power, but find that your heart rate is higher, that would mean you are losing fitness (or are hungry, over-tired, etc.).

Relationship between Heart Rate and Power

Heart Rate (bpm)	↓	↓	↑	↑
Power (watts)	↑	↓	↑	↓
Outcome:				

-  This is normal. No problem here.
-  This is isn't the right direction. Time to make a change.
-  This is great. Good job.

So, power meters are incredibly valuable because they give us concrete evidence that we are becoming stronger or weaker riders over time, something that has not been available to non-professionals before very recently. To really evaluate your training the way the pros do, measure the amount of power that you can exert at a specific percentage of your maximum (or threshold) heart rate. This is known as your “relative power per cardiac cost.” A good test ride for this measurement is the “2 by +60 by 2 Minutes” ride in the Sally Edwards Library of Rides on the Saris.com website.

Having said all this, the best way to learn about your power meter is to use it. You might start by riding the “Soar into the Stratosphere - Up 10 down 5” pyramid ride that follows. You won't feel like a turkey getting roasted, but you will feel what it's like to get into the hot, hard, and higher zones of power riding. Ride this ride and feel the heat with your newfound thermometer—the power meter.

Ride with power!

Sally Edwards, MA, MBA