6 POWER METERS TESTED

BY
ACHIM SCHMIDT PHD

SRM
CRANK BASED
POWER METER

IBIKE NEWTON PLUS
POWER
CYCLING COMPUTER

GARMIN VECTOR
PEDAL BASED
POWER METER

POWER TO GO

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Introduction

The bike of a professional cyclist is light and expensive - and it has a power meter installed. Power measurement often makes the difference between good and bad training. How power meters work and what systems are the best are shown in this review.

Power meters are small and expensive, crammed with technology. They must withstand rain, heat, dust, and snow. They must work. They must be accurate.

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QUARQ
CRANK BASED
POWER METER

POWER TAP
REAR HUB BASED
POWER METER

POLAR KEO
PEDAL BASED
POWER METER

Many cyclists now focus their training according to power values. Power meters are of course indispensable to the professional cyclist, but now more and more amateur and enthusiast riders want power measurement devices on their bike.

The Technology

It all sounds quite simple. Most power meters operate on the same principle: when the pressure applied by the cyclist deforms the crank, the pedal, or hub, an electronic sensor (a strain gauge or piezoelectric element) is also deformed. This sensor transmits the degree of deformation as an electric pulse to the measuring electronics, which in turn sends a signal to the display device, a bike computer, located on the bike's handlebars.

So far, so good. And while it sounds simple, up to now most manufacturers have had a very difficult time to bring well-functioning power measurement systems to the market. One manufacturer had water issues from seal leaks. Another manufacturer had to iron out problems stemming from vibration-prone sensors. Many simply had problems with consistent accuracy. Many products had great acclaim in the first light of day, only to fail after a short time and say goodbye. Others were announced at an early stage by their creators, only to delay promised first delivery every six months.

The complication of cyclist power performance measurement is not the measurement process itself. Torques are measured in all types of engineering. The difficulty in bicycle power measurement lies rather in the special requirements for cycling power meters:

- Waterproof
- Easy to use
- Accurate
- Accuracy independent of temperature
- Drop resistant
- Vibration resistant
- Durable

To combine these properties in an affordable device has caused many design concepts to fail.

A Few Words on Accuracy

Anyone interested in a power meter will, apart from the price, always ask: what is the accuracy? The manufacturer will not stand up openly and give answers to this question, but rather say: one to three percent deviation. That sounds good, but unfortunately, the potential buyer has no way of verifying those claims. The values of the six devices in our test field are separated by slightly more than three percent.

However, differences in accuracy is not a serious shortcoming. As long as a system is in itself consistent, so that “300 watts” is still, two years later, “300 watts”, the athlete can use the data for objective analysis. Absolute numbers become most important when the athlete’s performance targets, sent from his coach, do not coincide with those of the athlete’s power meter. In such a case, it may happen that the athlete is either overloaded - or under-challenged. In case of serious differences, they need to be resolved.

Jumping Power Numbers

When a cyclist moves his muscles on a bike, varying pedal forces cause fluctuating power values. If these fluctuating power values were displayed, the cyclist could not do anything. Therefore, the manufacturer filters the display to smooth the power numbers presented. In fact, the systems in this review detect the force fluctuations much more often than are indicated on the bike computer display.

In general, sensor data is measured at a rate of several hundred Hertz, but only the mean power value per second is transmitted to the display. This average is further smoothed over a time interval which is settable by the user. Thus, the averages of several seconds of the power measurements are what is actually displayed on the screen.

Assuming a sampling rate of 360 Hertz, 360 torque values are calculated per second. At a cadence of 60 revolutions per minute, there is one revolution per second, thus providing a torque measurement for each degree of crank rotation.

The Durability Question

If you invest €1,000 to €3,000 euros (US$1,300 to US$3,900) in a power meter, you intend not only to have a summer of fun, but many, many seasons. The fact that such long-term use is possible is shown actually only by SRM, because their devices have been in use for over 25 years. Many power meter companies have not even celebrated their tenth anniversary.

SRM uses cranks to measure performance. The advantages of this system are obvious: the crank is the most robust component on the bike; the chain can be replaced when worn. The crank is relatively immune to impact and bad falls.

It's different for pedals and hubs. Especially in the pedal, there is very little space for electronics, which increases the design effort. In the two pedal systems in our test, the transmitters are located outside the pedals themselves. The rotating pedal axle must be much better sealed than with a conventional pedal, because leaks would destroy the valuable electronics. In addition, racers in particular continually push on the pedals. The electronics must therefore be very robust so that it they are not harmed by such violent shocks.

The Installation

The days in which the installation of a power measurement system requires an apprenticeship as a bicycle mechanic are over. Nevertheless, the devices tested in this review require different assembly demands on their users. Most straightforward is the assembly of the iBike Newton which, like an ordinary bicycle computer, is mounted on the handlebars or stem. Then, you attach the combined ANT+ cadence and speed sensor on the chain stay, and also a spoke magnet, and off you go.

In SRM and Quarq, you make a simple installation of the display computer, and then the crank is replaced. You need to pay close attention to the built-in bottom bracket, otherwise the new crank does not fit. A crank change happens nowadays in a few minutes with an allen key. The assembly of the magnet for the crank is a bit trickier in a carbon frame, due to the very different bottom bracket. It's best to glue the small magnet with two-component adhesive, but manufacturers also supply special brackets for bolting to the bottom bracket shell. However, this means more work than bonding. After this you only need the speed sensor installed, and then both ANT+ sensors are coupled to the display device.

The simplest installation is certainly on the PowerTap power meters. Simply change the rear wheel, pair the PowerTap (ANT+) to the computer and off you go.

The two pedal systems are different in the pedal assembly. In the Garmin the pedal and a sensor is screwed in the cranks. In the Polar you have to pay attention to several things: a marker in the pedal axle is oriented in the forward direction of travel. Once the correct position is found, the axis is fixed with a special tool and is locked to the pedal with a flat key.

In both pedal systems the handlebar computers are installed and a pairing is performed.

For any of these systems it is feasible to install them in as little as 20 minutes.

Calibration

The calibration of the power meter is critical to its accuracy. Due to temperature fluctuations, their measurement sensors' response is affected. Through a calibration - or more precisely, a zeroing adjustment - this low tolerance factor is eliminated. "After temperature adjustment, the change is only a few watts," says Stefan von Kempen of SRM. SRM, PowerTap, Quarq and Garmin perform the temperature calibration automatically, but they can also be partially calibrated manually. The Polar Keo system must be calibrated manually by a short procedure.

Whenever there is no pressure applied to the pedals, zero torque should be measured. A calibration prior to each ride zeroes the power meter reading.

Much more important is the precise factory calibration of the pedal, the hub or the crank before delivery. The crank is loaded with a known weight, for example, in SRM and Quarq, and with known crank length and weight, one can calculate the applied torque. The measured value with the sensor is multiplied by a factor, that returns the known applied torque, resulting in an accurate measuring system. In Quarq this process can be done even with an app and a video itself.

Software

Unlike a conventional bike computer, the biggest benefit of a power measurement system becomes apparent only in the use of analysis software. Unlike SRM and iBike, not all manufacturers in our test field have made the effort to develop their own ride analysis software. The SRM software leaves little to be desired and is very user friendly, particularly in the processing of the data. Its compatibility with other power meters, however, is not possible. And iBike Isaac software is very graphical, with many features that experienced professionals will appreciate right away.

Quarq does not have its own software. Instead, the cyclist uses Training Peaks (WKO+), Golden Cheetah, (free) or Strava. There are now smartphone apps with which display power (assuming the smartphone is enabled to receive the power sensor data), and for the Quarq an app can be used to carry out the calibration.

For all these software alternatives, we note that their functional scope is huge. A full understanding of their complex functions can take months for an amateur to learn, because of the complex scientific theories and mathematical models on which the they are based.

The Test Design

Because there is no measuring device with which one can identically test different power meters in practice, the assessment of the accuracy of a power meter is a complicated subject. Without the availability of a reference system we decided to conduct a standardized outdoor test and a standardized indoor test.

We started with durability testing. Then there were tests on braked rollers. For this purpose, a test protocol was programmed with 100W and 200W respectively about nine minutes. During the nine minutes the cadence every three minutes was increased from 60, to 75, to 90. The metronome gave the test driver the cadence. Each system was tested multiple times on different days. The values of the first test could be reproduced. It must be taken into account in tests such as these that the cadence rhythm may vary slightly always, although the average cadence remains constant. The Newton could not be included in this indoor test. Caption in table below: "Indoor test: tested power systems on indoor rollers, with cadences of 60/75/90, at two controlled power levels (100W, 200W)"

Trittfrequenz	Quarq		SRM		Powertap		Garmin		Polar	
60	103	205	102	207	105	204	100	190	94	187
75	104	203	99	199	104	200	97	191	93	189
90	100	203	100	199	104	203	107	187	97	191
Mittelwert	**102,3**	**203,7**	**100,3**	**201,7**	**104,3**	**202,3**	**101,3**	**189,3**	**94,7**	**189**

Tabelle Indoortest: Die Leistungsmesser auf dem Rollentrainer bei den Trittfrequenzen 60/75/90 in zwei Leistungsstufen (100 W, 200 W).

After installation and calibration of the measurement system, the weight was dialed in for the system with bike, rider and bottles, at a constant 93 kg (205 pounds). Other variables were fixed including 8 bar (116 psi) air pressure in the tires and top [hoods] riding position. The test rider went on four rides per system, testing on a road with 4 % slope. Riding was held at a constant cadence of 75 RPM (via smartphone app with headphones), at a gear ratio of 39 x 23. After a few practice runs the test cyclist was able to complete the 500 m long path, each time within one second.

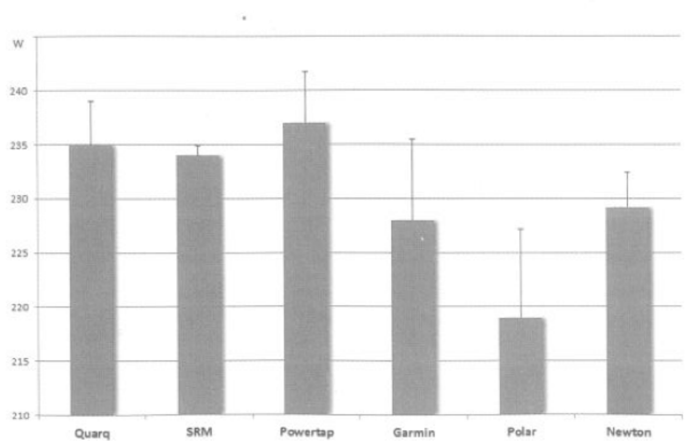
Shown in the graph are the mean values of the average results per unit system, and the corresponding standard deviation as a small bar—which indicates the consistency of the measured values.

The results of outdoor tests show a difference of 18W between the device with the highest value (PowerTap) and lowest value (Polar). This is good and shows that the manufacturer can realize for brand new products a low measurement uncertainty, and also that their factory calibrations work.

The indoor test also confirmed the outdoor test results, but here the Polar system indicated slightly lower values, and the value measured by Garmin in the 200W test was surprisingly low. A statement on the values of consistency, for months in extreme temperature conditions and vibrations, could not be made. Especially with the new products on the market, it will take some years before this can be assessed.

Caption in Table below: "Graphic field test: the power meter on the mountain. Cadence frequency 75; gear ratio: 39 x 23. Test Duration: 1 min 50 sec. Number of tests: four per power meter system"

Grafik Feldtest: Die Leistungsmesser am Berg. (Trittfrequenz: 75 U/min, Übersetzung: 39x23, Dauer: 1:50 min. Anzahl Fahrten: vier Fahrten pro System).



Conclusion

A few years ago the buying decision was clear: SRM. And in 2013 the German manufacturer still sets the standards, but the competition is now on its heels. PowerTap offers an affordable and very easy to assemble system, and the iBike Newton offers an even more affordable alternative. With Quarq there is a serious crank competitor, and in pedal systems Garmin has the lead.

Besides cost there ultimately is also the fundamental question of the installation: crank, hub, pedal, or just on the handlebars.

Product Reviews

SRM System 7

As the granddaddy of all performance measurement systems, the SRM System 7 makes an impeccable impression. The power meter system is impressive and high quality and its PowerControl 7 display apparatus is visually and technically at the state of the art for modern bicycle computers. With five simultaneous displays the PowerControl 7 provides the user a good overview of his training. The easy controls of the PowerControl are not self-explanatory but easy to learn.

In contrast to Garmin displays, the PowerControl does not let the user configure the display screens. On account of SRM's cooperation with innumerable bike teams, the display can be ordered in many different colors to match team jersey and / or bike frame color schemes.

The SRM cranks work with most bottom brackets. The weight "penalty" for choosing the SRM crank over a conventional crank is a mere 100 g. The crank sensor is very rapid in response and the data displayed in near real-time appear quite plausible and with very little deviation. The SRM, Quarq and PowerTap were very close in our tests.

SRM's only disadvantage is that it must be periodically serviced. The device must be sent in for service every 1900 operating hours for the standard model or every 3000 hours for the Dura Ace model. In spite of this the SRM remains the reliable classic and is the first choice of most professionals.

iBike Newton +

The Newton refutes the thesis that power should be measured directly and cannot be determined exactly by indirect measurement. Thanks to its wind and acceleration sensors, incredibly accurate power values can be displayed.

How power is calculated inside the Newton remains a well-kept secret, but it has been improved considerably by the manufacturer since 2004.

The Newton's results are surprising. The Newton and combined speed/cadence sensor can be mounted quickly. After a ten minute out-and-back test ride the device is ready and shows, amazingly, almost exactly the same values as the other power meters tested.

Unfortunately, the English-only manual is incomplete and partially unintelligible. The display of the Newton is not great. In some cases it is not clear what is displayed. A full dot matrix display would be appropriate.

Despite this, the software has all the features you need for serious performance training and even has significantly more. The super-sensitive accelerometer allows even a view of pedal stroke.

Garmin Vector

Pedals and sensors have quality workmanship. The installation is really easy with only a small glitch as care must be taken to account for the small gap between the sensor and the crank. The sensor pairing and calibration require a few steps and is somewhat more complex than in the crank power meters. The Garmin has an automatic zero setting adjustment so that temperature changes do not matter.

Garmin pedals are compatible only with Look Keo cleats.

In practice, the display reacts to load changes quickly, and the right-left differences seem plausible and can be represented by more pressure on one side almost simultaneously in the display. The Garmin Vector measures numerous parameters about power and torque and also offers connoisseurs many new opportunities. As an uncomplicated newbie, Garmin Vector is likely to convince many interested parties. Whether the device is durable over extended usage in periods of years, the future will tell.

The Garmin Edge 810 display unit has a wealth of functionalities and options for customizing the measure of all things, even with regard to the processing power that allows a smooth operation of the touch screen. Many settings can be intuitively made in the logical menus. An instruction guide rarely needs to be at hand.

Polar Keo

In 2012 the cooperation of Polar and Look produced the first production-ready pedal power measurement system. During installation care should be used due to the required positioning of the pedal axle. For a system of this price, the fastening of the transmitter with cable ties looks like a tinker's solution, and only a long-term test could confirm the desired robustness. The device should be temperature calibrated (a 10 second process) prior to the ride and, in the case of relatively large temperature changes, during the ride. Otherwise temperature changes will affect the power values.

The Polar system is the only one not using ANT+ compatibility; instead, it relies on its own Polar-W.I.N.D. standard, which makes possible the use of Polar computers from the CS500 series. The values displayed were slightly under the average of the other products tested in this review. On load change the display responds slowly.

The disadvantage of the pleasant little CS600X computers is their somewhat complicated operation as compared to Garmin computers. The pressure point of the keys is too vague. An advantage of Polar Keo is the ability to differentiate left and right leg power, which can help performance differences. Compared to the other systems tested, its measured values measured appeared to be a little too low.

Due to its relatively high price and complicated computers, the Polar Keo system certainly has difficulties maintaining its position in the market.

Quarq

In 2005 Jim Meyer developed the prototype of the Quarq cranks, because as a triathlete he did not have enough money to buy a power meter. Today the Quarq crank with the ANT+ wireless standard is compatible with many display computers. An important advantage is its ability to change the battery independently. The system is simple: the Cinqo Saturn ring with its measurement electronics replaces the spider, for example, of Shimano or Campagnolo cranks, and is bolted to the crank, which also can be changed. Recalibration should then not be necessary. Also exciting is the possibility of displaying power differences between both legs. However, this can only be measured indirectly by the 360 degrees crank cycle, divided in two, with each leg assigned half of the total power. More of this type of left/right measurements are featured with pedal systems from Garmin and Polar, both of which independently measure left and right power.

The Quarq system is is easy to install, easy to maintain and shows plausible, reproducible power values. Sudden changes to power, such as in sprints, are displayed with very little time delay on the Garmin 800. The Quarq ELSA is a reliable, uncomplicated system with high accuracy.

PowerTap

A completely different and unique measurement concept is the basis of the PowerTap power meter. The measurement electronics have been relocated in the latest version with plastic located within the hub cap. If the hub becomes defective the electronics can be replaced and only a small part is returned. The battery is replaceable, and via a mini – USB connection, the user can update the firmware. Without the quick release hub the unit is very light—only 325g—and adds only a little more weight on the wheel. PowerTap hubs are now obtainable with aerodynamic Zipp rims. The cyclist can also easily build a wheel by purchasing the hub separately. The untested Joule cycling computer even comes with GPS.

In practice the PowerTap is completely straightforward and reliable. Its values show high consistency and are plausible even in high-intensity short-term loads.

The ease of moving the wheel to another bike, and also between athletes, are real arguments for a PowerTap. The hub tested made a robust impression.

Pricing (summarized from individual product reviews)

	Meter MSRP Euros	Display MSRP Euros	Total Euros	Equivalent in US$ US$1.3 to €1
Quarq	€1800	€200	€2000	$2600
SRM	€2677	€654	€3331	$4330
Newton Plus	€699	Included	€699	$909
Garmin	€1549	€520	€2069	$2690
Polar	€1949	Included	€1949	$2534
PowerTap	€999	€100	€1099	$1429

Weight

	Meter Weight Grams	Display Weight Grams	Total Grams	Meter Location
Quarq	742 g	141 g	883 g	Crank
SRM	823 g	69 g	892 g	Crank
Newton Plus	95 g	Included	95 g	Handlebar
Garmin	309 g	141 g	450 g	Pedal
Polar	350 g	132 g	482 g	Pedal
PowerTap	325 g	141 g	466 g	Rear wheel hub

Notes:

Meter weight includes the part the meter replaces. In the case of SRM, the SRM replaces the crank. The SRM combination of sensor and crank is reported to be 100 g heavier than the standard crank it replaces.

For completeness in the cases like Quarq, where a display was not specified but is of course needed, the weight of a Garmin display of 141 g was used to show the complete system weight. This applied to Quarq and PowerTap above.

Interview with Uli Schoberer

Uli Schoberer is the man with the most experience in building bicycle power meters. With his SRM equipment, he has been in the business since 1986. Meanwhile, the competition has caught up.

"Mr 80 Percent"

Q: Mr. Schoberer, how many pro cyclists have at present an SRM on their bike?

A: I think about 80%

Q: In terms of performance measurement, SRM is still the top dog. Do the many new power meters developed in recent years have you worried?

A: I don't worry, but sometimes it is not so nice to see your own ideas copied, and then sold as "news" to unsuspecting customers.

Q: Where did you get the idea to build a power meter for cycling?

A: I was a keen amateur cyclist, interested in training theory, and I quickly came to the conclusion that without power measurement no reasonable control of training is possible.

Q: Why do we hobby cyclists need a power meter?

A: No matter at what level one is, only with a measuring system can the cyclist quantify his effort, monitor his training progress, and adjust his training.

Q: Your SRM system works with strain gauges in the crank. How do you see efforts simply to calculate the power?

A: The indirect calculation of the power can work - but only under certain conditions: on closed racing tracks and some climbs, but only in calm weather. On the open road, with changing and unpredictable terrain, and where wind influences the calculation of the power, reasonable accuracy is hardly possible because the wind and terrain variables change constantly, making each section of road different, and changing the power calculations. Accordingly, most performance metrics which are offered by bicycle computers without a power meter are only rough approximations.

NOTE: ***This translation was made with Google Translate, with appropriate corrections. A reader fluent in German may find more supporting information in the original article as published by RennRad in the native German.***