White paper

Cycling Performance Test

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Introduction

A bicycle is one of the greatest human inventions. It dramatically reduces the cost of transport; the energy required to travel a given distance. Compared to animals that walk on four legs, humans consume much more energy by walking on two. By replacing feet with wheels, humans take back the advantage. A bicycle reduces the cost of transport as much as 90% when compared to walking and running.

The cycling mechanics are simple. A rider who moves at a constant speed must balance the used muscle power with the forces that work against the rider. There are three forces that resist the rider: gravity, roll and air (Fig. 1). Gravity resistance depends on the gradient and can have both negative and positive values. Roll resistance is almost non-existent in the road bikes due to a high tire air pressure. By contrast, roll resistance may play a significant role in the mountain bikes. The work done against air resistance is proportional to the third power of speed, which makes air the only significant source of resistance at high speeds.

Technology can assist the rider to achieve higher speed, for example through improved aerodynamics, but technology cannot assist the rider to achieve higher power, because power is solely determined by the capacity of muscles. This assuming, of course, that a bicycle is not driven with the help of an electric motor.

The current paper describes Polar **Cycling performance test** that allows user to determine his/her cycling performance. As the test measures power and not speed, the result will be independent of the bike used. The result will depend only on aerobic power that muscles can supply. In addition to a performance testing, Cycling performance test supports power zone updates.

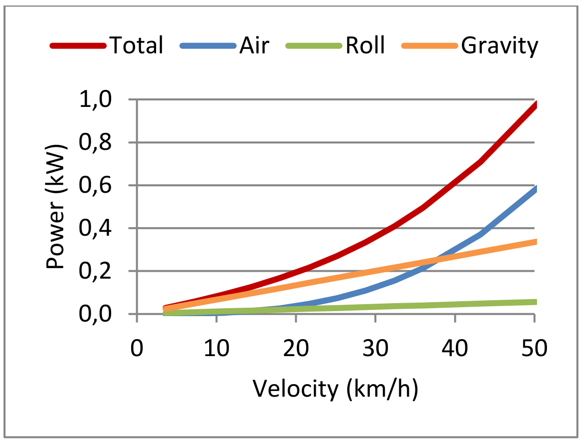

Figure 1. Theoretical power due to air, roll and gravity resistances as a function of speed. Gravity resistance is based on constant 3% gradient. The total mass of the bike and rider is 82 kg.

Physiological background

Amongst the first attempts to mathematically describe human performance was made by Nobel-winning scientist A.V. Hill in 1925.[1] He noticed that human average speed over a given distance in running and swimming follows a hyperbolic curve. By changing speed to power, the relation between maximal power P_{max} that can be sustained over duration T is given by

$$P_{max} = \frac{W_{ana}}{T} + P' \qquad (1)$$

where W_{ana} describes anaerobic work capacity and P' sustainable aerobic power.

It can be seen from Eq. (1) that when T approaches a very large number, the term W_{ana}/T approaches zero. This suggests that the average power over a long duration is independent of speed. This is called a **critical power**; asymptote of power-duration curve (Fig. 2).[2]

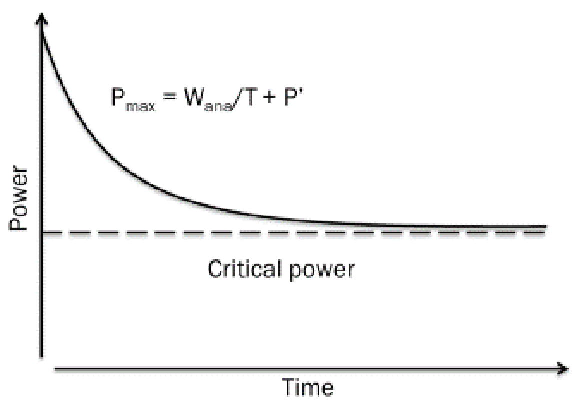

Figure 2. Critical power is determined as the asymptote (broken line) of the power-duration curve (solid line).

Hill himself noted that his equation describes performance in short- and middle-distance running (up to 12 minutes) but fails to describe the decline in power that occurs in long-distance running, such as marathon. However, the critical power concept has remained very popular in cycling.

Critical power can be very laborious to obtain. According to the estimates, it takes 3–7 tests of different durations to determine critical power.[3] As a result, there was an increasing demand to replace critical power with a more practical **functional threshold power (FTP)**; an average power that a cyclist can maintain for 60 minutes.[4]

The justification for FTP is that it relates to lactate threshold, defined as 1 mmol/l increase in blood lactate over exercise baseline.[5] Recently, also a 20-minute test has often been taken instead of a 60-minute FTP test.[6,7]

To allow maximum flexibility, Cycling performance test supports 20-, 30-, 40-, and 60-minute tests. When shorter than a 60-minute test is taken, average power is always converted to a 60-minute FTP (Table 1). For example, if average power over a 20-minute test is 200 W, a 60-minute FTP is 200 W * 0.95 = 190 W.

Table 1. Average power conversion to FTP.[4]

Duration over which mean power is taken	*Mean power to FTP conversion factor*
20 min	0.95
30 min	0.9625
40 min	0.975
60 min	1

Technological background

As the name FTP implies, the main outcome of Cycling performance test is power. Thus, the test requires power sensors connected to your Polar device. For the list of compatible sensors, visit Polar website. You can also use a heart rate monitor, but that is optional. The test does not rely on heart rate to determine results.

An example of a bicycle power sensor is a strain gauge sensor that measures torque. Multiplying torque with angular velocity yields to power. The sensor itself is typically placed inside a pedal or a crank. Some indoor bikes have built-in power sensors, but you can also buy separate power sensors that can be installed on any bike. The sensor also has a wireless transmitter for an exercise tracker connection.

The bicycle sensor's output is mechanical power given in watts. The result can also be divided by weight for comparison. Mechanical power is the power that muscles supply on a bike and cannot be converted to calories consumption.

Test protocol

Prior to start, the user is asked to select a 20-, 30-, 40- or 60-minute test. Minimum duration for a successful test is 20 minutes. If the user chooses longer duration but fails to reach it, we still calculate the result based on the next, shorter duration. For example, if the chosen duration was 40 minutes, but the test was finished after 35 minutes, the calculated FTP is based on a 30-minute test.

The test is preceded by a warm-up and followed by a cool-down. During the warm-up the user can make sure that all sensors work as expected.

The idea of the test is to maintain steady power. This power is the maximal power that a rider can sustain for the duration of the test. To help the user to determine proper power we derive target power either from the user's background information or from the last test result. The first option is used only when the test is taken for the first time.

Please note that we always give your 60-minute FTP as a result regardless of what duration you chose (see Table 1 for conversion).

Interpretation of results

The main test result is FTP; the estimate of 60-minute average power. FTP can be used directly to indicate changes in aerobic performance. FTP cannot be compared to the other riders though. Also, if the user's weight is changed, the performance may change despite of FTP remaining the same. FTP depends mainly on aerobic power but may be affected by technique. Especially, when the rider is unaccustomed to the pedals with a locking mechanism, he/she probably cannot activate knee and hip flexors to produce power. As a result, FTP is likely to improve with experience.

FTP is given in watts and therefore depends on the size of the rider. Thus, we also calculate the relative power by dividing FTP with the user weight. This number, given as W/kg, can be used in comparison between the riders of different sizes. Relative power depends on the relative amount of muscle that a rider can activate. Thus, the professional cyclists who have a substantial amount of muscle concentrated to hips and thighs, usually generate high relative power values.

After the test, cycling power zones are updated automatically if the user agrees to this. The zone definitions are: 1. zone 60–69% of FTP; 2. zone 70–79% of FTP; 3. zone 80–89% of FTP; 4. zone 90–99% of FTP; and 5. zone >=100 of FTP.

The test also calculates VO2max estimation. However, this is specific to cycling and should not be compared to other VO2max estimates that Polar calculates.

Preparation for test

The test should be taken after an optimal preparation. This includes training lightly for 1–2 days prior to the test, following normal sleeping routines, and eating carbohydrate rich food on the day preceeding the test. For the highest reliability, take the test indoors. If you decide to take the test outdoors, be aware that the test cannot be paused when you, for example, hit the traffic lights. All interruptions lower your average power. Thus, it pays off to plan a route with minimal obstacles before taking the outdoor test. Note that even the shortest 20-minute test may require 10–15 km of open road.

Advantages

The advantages of Cycling performance test are:

- Based on the well-known FTP test
- Allows cycling performance tracking
- Automatic determination of the power zones when the test is finished
- Indoor and outdoor tests are allowed
- Visual guidance helps maintain steady power during the test
- Supports 20-, 30-, 40-, and 60-minute tests.

Limitations

The most obvious limitation is that the test requires power sensors. For those who do not want to invest to the power sensors, we recommend finding an indoor bike that has a built-in power measurement system. In fact, an indoor test is the most reliable test as it has the smallest amount of varying factors. The next limitation is a general formula (in Table 1) that is used to convert a sub-60-minute result to a 60-minute FTP. As this relation varies individually, we recommend that you always repeat the test by using the same duration. By doing this, you can follow your development and seasonal variations.

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