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Introduction

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

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

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

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

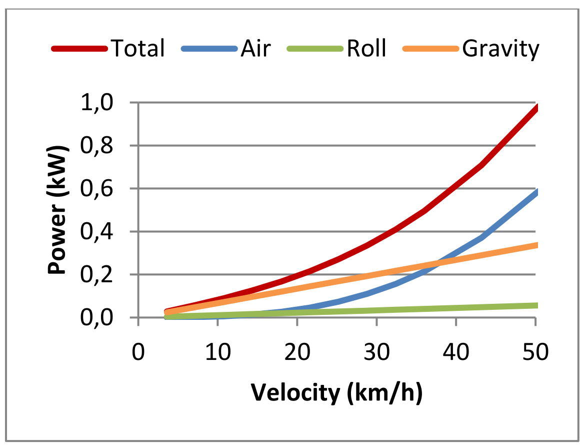

Figure 1. Theoretical power due to air, roll and gravity resistances as function of speed. Gravity resistance is based on constant 3% gradient. Total mass of bike and rider is 82 kg.

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 given distance in running and swimming follows a hyperbolic curve. By changing speed to power, relation between maximal power P_{max} that can be sustained over duration T is given by

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

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

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

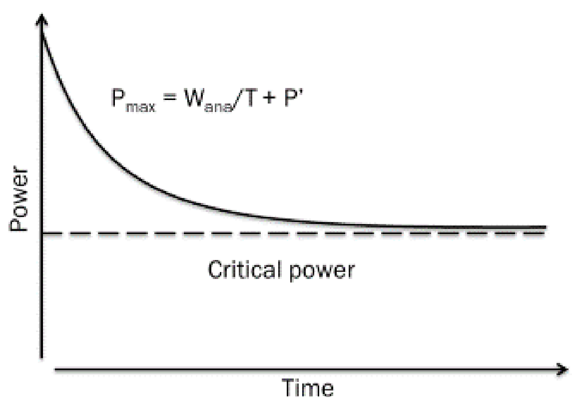

Figure 2. Critical power is determined as the asymptote (broken line) of the power-duration curve (solid line).

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 over long-distance running such as marathon. However, critical power concept has remained very popular in cycling.

Critical power can be very laborious to obtain. According to 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 more practical **functional threshold power (FTP)**; average power that cyclist can maintain over 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 20-minutes test has been often taken instead of 60-minutes FTP test.[6,7]

To allow maximum flexibility, Cycling Performance Test supports 20-, 30-, 40-, and 60-minutes tests. When shorter than 60-minutes test is taken, average power is always converted to 60-minutes FTP (Table 1). For example, if average power over 20-minutes test is 200 W, 60-minutes 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, main outcome of Cycling Performance Test is power. Thus, test requires power sensors connected with your Polar device. For the list of compatible sensors, visit Polar website. You can also use heart rate monitor, but that’s optional. Test does not rely on heart rate to determine results.

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

Bicycle sensor’s output is mechanical power given in watts. Result can also be divided with 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, user is asked to select either 20-, 30-, 40- or 60-minutes test. Minimum duration for successful test is 20 minutes. If user chooses longer duration but fails to reach it, we still calculate result based on the next, shorter duration. For example, if chosen duration was 40 minutes, but test was finished after 35 minutes, we calculate FTP based on 30-minutes test.

Test is preceded by warm-up and followed by cool-down. During the warm-up 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 rider can sustain for the duration of the test. To aid user to determine proper power we derive target power either from user’s background information or last test result. First option is used only when test is taken for the first time.

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

Interpretation of results

Main test result is FTP; estimate of 60-minutes average power. FTP can be used directly to indicate changes in aerobic performance. FTP cannot be compared to other riders though. Also, if user weight is changed, performance may change despite of FTP remaining same. FTP depends mainly on aerobic power but may be affected by technique. Especially, when rider is unaccustomed to 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 size of the rider. Thus, we also calculate relative power by dividing FTP with user weight. This number, given as W/kg, can be used in comparison between riders of different size. Relative power depends on relative amount of muscle that rider can activate. Thus, professional cyclists who have 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 user agrees. The zone definitions are: 1. zone 55–74% of FTP; 2. zone 75–89% of FTP; 3. zone 90–104% of FTP; 4. zone 105–119% of FTP; and 5. zone >=120% of FTP.

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

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

Advantages

The advantages of Cycling Performance Test are:

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

Limitations

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

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