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Introduction

It has been postulated that endurance running has played a crucial part in our evolution.¹ Compared to chimpanzees – our closest living relatives – humans have several features that enhance endurance running ability: long legs connected with elastic tendons that save energy and narrow, flexible waist to improve balance. While motivation to run fast may have

changed from the pursuit of prey to beating the clock, the physiology has remained. The top runners of the ancient savannas and modern cities must have had high aerobic fitness, good running economy and unrivaled ability to resist fatigue. Therefore, it is no surprise that a variety of tests have been developed to obtain these attributes.

Running tests are sorted into three main categories: time and distance trials and ramp tests. Time and distance trials are conducted at optimal speed that must be known prior to start. In a ramp test, a priori assumption about the optimal speed is not required. Ramp tests are conventionally conducted at a laboratory. From runner's perspective, frequent laboratory testing causes accumulated expenses and those living in thinly populated areas may not have access to a running laboratory. To achieve the easiness of time and distance trials and the flexibility and versatility of ramp tests, we have designed **Running performance test** that is based on ramp protocol and requires only a heart rate monitor and speed tracking system. This paper describes how this test works.

Physiological background

Endurance running needs a constant supply of oxygen. Thus, maximal oxygen consumption (VO₂max) is a strong predictor of endurance running performance.² VO₂max is typically

obtained by a ramp test, in which speed and power are increased until oxygen consumption saturates (Fig. 1). The lowest speed and power at which VO₂max occurs are called **maximum aerobic speed (MAS)** and **maximum aerobic power (MAP)**. MAS and MAP are determined by both VO₂max and running economy. Thus, MAS and MAP offer a more practical way of tracking performance and obtain individualized training guidance than VO₂max. Through Running performance test, these features are now available on your Polar watch.

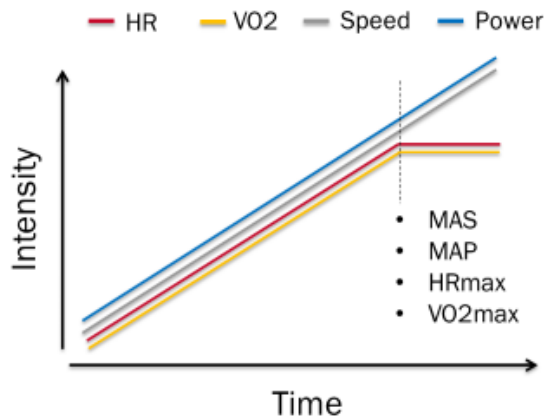


Figure 1. Illustration of ramp test protocol. Maximal oxygen consumption (VO₂max) and maximum heart rate (HR max) are taken from the plateau at the end. Maximum aerobic speed (MAS) and power (MAP) are taken from the turning point between the slope and the plateau.

Technological background

Time and distance trials must be conducted at a constant, optimal speed and they end when certain time or distance is achieved. By contrast, a ramp test is conducted with a gradually increasing speed without prior knowledge of the speed at the end. A ramp test ends to exhaustion or when certain criterion, such as fractional heart rate, has been exceeded. In this section, we describe how a ramp test can be conducted and results delivered without laboratory equipment.

University of Montreal Track Test

Running performance test is based on the **University of Montreal Track Test (UMTT)** protocol.³ As the name implies, UMTT is taken on athletic track and uses marker cones placed next to the track to control speed. The downside of this approach is that the number of cones passed and time between the cones must be supervised. To avoid this unnecessary hassle, we use a GPS-enabled smartwatch to guide user through the test.

Protocol

Here we explain the Running performance test protocol by describing how it progresses and how it is completed.

Progression The basic idea is that user follows a target speed that increases gradually

throughout the test. To allow users of different abilities to take the test, the initial target speed is, by default, 6 km/h. This is a walking speed for most of us. Advanced runners may adjust the initial speed in test settings. The allowed range is 6–15 km/h. The rate of change of target speed is constant, 1 km/h for every 2 minutes.

Completion The test is completed when 85% of maximum heart rate (HR max) has been achieved. However, user can continue until exhaustion, if they want to determine their running performance with the highest possible accuracy and update HR max.

Maximal or submaximal test

To allow maximal flexibility, we have implemented two versions of Running performance test. The **maximal test** is ideal for experienced runners who want to determine their running performance with highest possible precision and update HR max. It takes grit to take the maximal test though, as running continues until exhaustion. For a more “friendly” version, user can take the **submaximal test**, which means running until 85% of HR max has been reached but stopping before exhaustion.

There is no need to decide between the maximal and submaximal test before starting the test. When 85% of HR max has been reached during the test, user can stop there and

get a submaximal test result. Alternatively, user can decide to go all-out and take the maximal test.

Test guidance

Running performance test is a **speed-guided** test, which means that user must follow the target speed as precisely as possible. To keep user at the right pace, we use speedometer as a visible aid (Fig. 2) and vibration/audio signals to warn about going too fast or slow. A weak signal is given when the deviation between the current and target speed is more than ± 1 km/h. This is followed by a stronger signal if the deviation exceeds ± 2 km/h. If the deviation exceeds ± 3 km/h, the test is automatically aborted unless the target speed is restored within 10 seconds.

The test supports **auto stop**. To quit the test, user can just stop running. To avoid unnecessary stops, auto stop is activated after 10-second delay. The auto stop feature does not compromise any results as the data gathered when the runner doesn't move or moves very slowly is neglected from the calculation of results. Alternatively, the test may be stopped at any time by pressing a button, in which case the test stops immediately.

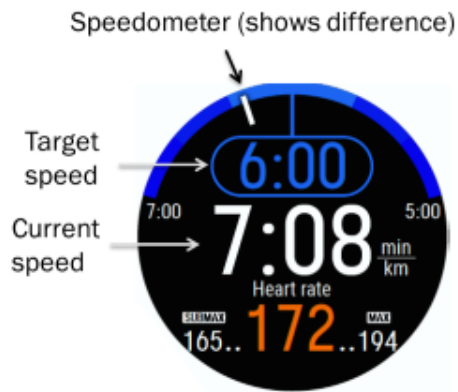


Figure 2. Illustration of watch face during the test. The top half is dedicated to speed guidance. The minimum heart rate requirement, 85% of HR max, is shown under the SUBMAX symbol in the bottom left corner.

Results

The following results are delivered immediately after the test:

Submaximal test

- MAS
- MAP
- VO2max

Maximal test

- All of the above
- HR max

All results are calculated automatically. MAS and MAP are taken from the speed and power at the end of the maximal test. In case of the

submaximal test, we use test data and the HR max taken from physical settings to work out MAS and MAP. To get the most reliable results from the submaximal test, HR max should be correctly set in physical settings. VO2max is calculated based on the speed or power values that we recorded during the test. Note that HR max is only available from the maximal test.

Validation

UMTT has been scientifically validated. It was concluded that there was no significant difference between laboratory-derived MAS (15.9 ± 2.6 km/h) and UMTT-derived MAS (15.8 ± 1.9 km/h).⁴ Another study made similar findings with laboratory-derived and UMTT-derived MAS equating to 17.1 ± 2.7 km/h and 16.7 ± 1.3 km/h, respectively.⁵

Advantages

The major benefits of Running performance test are:

1. Follows the UMTT protocol, which is a scientifically proven method to determine aerobic performance in running
2. Automatic determination of speed, power and HR zones
3. Allows individualized training guidance
4. No prior knowledge of endurance running performance is required

5. The submaximal test acts as a steppingstone to testing world
6. The submaximal test allows fitness tracking as often as you like
7. Accurate determination of HR max through the maximal test.

How to interpret results

MAS, MAP and VO2max are indicators of your aerobic performance in running. You can use any one to track your development. If you want to compare yourself to other runners, we recommend using MAS or MAP. VO2max is best used as a general aerobic fitness indicator.

If you enjoy mountain running, MAP is your preferred choice because power considers altitude variations. If you mostly run in flat terrain, MAS is an equally good choice as your main performance indicator.

We use MAS and MAP to automatically set speed and power zones in your running sport profiles. HR max is used to update heart rate zones in all sport profiles. We ask your permission before updating anything. Moreover, we never update custom zones. Only default zones can be updated.

When your training zones are up to date and based on your measured MAS, MAP and HR max, your training guidance will be individual. The detailed explanation on how to train at each zone is beyond the scope of this

document, but Fig. 3 outlines training zones' relation to each other. In summary, HR zones cover the aerobic part of your training with high resolution whereas speed and power zones take you to the anaerobic level. In practice, this means that speed and power zones can be used in interval training with great efficiency.



Figure 3. Illustration of heart rate (HR), speed and power zones. Maximum aerobic speed (MAS) and power (MAP) equate to lower limit of zone 4.

Practical tips

To ensure optimal preparation, avoid heavy exertion 1-2 days before the test and follow your normal eating and sleeping routines. Make sure to select a flat route such as running track as it is assumed that your effort increases in parallel with speed throughout the test. If you're using GPS to track speed, select location that is free of tall buildings or trees as they may block satellite view and thus compromise accuracy. After the test, give yourself a day or

two to recover, especially if you took the maximal version of the test.

The choice between the maximal and submaximal test depends on your needs. The maximal test is the best way to ensure that your HR max is always up to date. However, as the maximal test pushes you to the limits of your performance, it needs optimal physical and mental preparation. In addition, recovery may take few days. As a result, we recommend taking the maximal test every three months. The submaximal test is much less demanding and can be taken as often as you like. If your HR max is up to date, the submaximal test is also very accurate.

Limitations

The test does not measure VO₂max. Thus, it's not an alternative to a laboratory test. On the other hand, VO₂max is only an indirect indicator of running performance. More direct indicators, such as MAS and MAP, are available through Running performance test. The test has two versions: maximal and submaximal. The maximal test is probably too hard to take on weekly basis. The submaximal test can be taken as often as desired, but results may sometimes differ from the maximal test. The test assumes a gradually increasing effort that is achieved by a gradually increasing speed. If either of these assumptions is not met, perhaps due to bad

GPS reception or minor slope variations, the test results may be compromised. User can avoid these obstacles by selecting a location that has no visible hills and has clear view of the sky. This small investment to preparation is worthwhile as it ensures reliable results.

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