POLAR

PIONEER OF WEARABLE SPORTS TECHNOLOGY

White paper

Polar Running Index

April 4, 2021

Polar Research Center

Contents

1   Abstract

Running Index is a simple and convenient way to determine running performance - it's automatically calculated on (almost) every run. Running Index takes speed and heart rate information and squeezes it into one validated and comprehensible number that reflects running performance.

As a frequently updated number, Running Index is a powerful tool to follow changes in endurance fitness and predict future performance. You can also compare your performance against others in your reference group.

Running Index is dependent on running conditions. For example, running on difficult terrain may result in a lower Running Index compared to running on gravel or road. This is because extra work is needed to avoid obstacles and correct your balance, inevitably increasing your heart rate at any given speed. Thus, Running Index should be interpreted as an estimate of your running performance under the current conditions.

In this paper, we go through the physiological and technological background of Running Index in order to answer the most common questions that may arise.

2   Physiological background

Running performance identifies how fast you can run a given distance. This is mainly influenced by your aerobic capacity, your body weight and, to a lesser extent, your running economy. Let's briefly look at these factors and how they affect your running.

First, aerobic capacity means how much oxygen your muscles can utilize (liters per minute). In endurance events the ability of lungs to intake, heart to supply, and muscles to utilize oxygen is of paramount importance. The higher the aerobic capacity is, the higher the endurance performance.

Second, your body weight is likely to affect your performance. Imagine a truck that has a small engine - it won't perform very well, but if you keep the engine, replace the truck with a Formula One car, you improve the performance significantly. Thus, the size of your body in relation to your engine (your heart), will largely determine your performance in endurance events. To make up for differences in body size, the standard measure of aerobic capacity is expressed as liters of oxygen per minute per kilogram of body weight.

Third, your running economy is identified as how much oxygen you need to run a given distance. The typical value for humans is 0.2 ml of oxygen per meter per kg of body weight. The lower this number is, the higher your running economy is - and the faster you can run. Currently, the exact reasons why some individuals have better running economy than others are not fully understood. It is, however, often observed that more experienced runners have better running economy. Thus, there is good reason to believe that you can improve your running economy simply by running.

Polar Running Index (RI) combines the aforementioned factors into one number that reflects your running performance. Please note that RI is determined whilst you run, therefore, your body weight that is stored in Physical Settings in the Polar Flow service has no influence on RI. To induce change in RI, a change in heart rate or speed is usually required. For example, if your speed increases at a certain submaximal heart rate, your RI improves. Conversely, if your speed decreases but heart rate remains the same, RI falls.

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3   Technological background

Here we go through the basics of technology that are behind the determination of RI. For starters, let us remind you that RI is only available in running sport profiles. For example, if you select outdoor exercise and run, Running Index will not be calculated.

3.1   Requirements

Running Index is calculated from speed and heart rate information. If your Polar watch has integrated altitude sensor, that information is also used. With altitude information, we can compensate the effect of slopes. If altitude sensor is not available, RI is calculated, nevertheless. In that case, it is worth remembering that on uphill routes, your RI is likely to be lower than on even ground, and the opposite case is true for downhill routes.

In addition to exercise heart rate, RI requires your **maximal** and **resting heart rate** information. Maximal heart rate is the highest heart rate that you can achieve in all-out exercise. Resting heart rate is the lowest heart rate at complete rest, yet not sleeping. You can find and adjust these numbers from Physical Settings in the Polar Flow service.

3.2   Calculation of Running Index

Running Index is calculated automatically whilst you run. We have designed an algorithm that intelligently filters out small interruptions – meaning that tightening your shoelaces or stopping to sightsee won't mess up your RI calculation. The algorithm can also handle signal disturbance that may occur as you enter a tunnel or encounter other obstacles that can interfere with satellite visibility.

Running Index is the estimation of your maximal oxygen uptake (VO2max) expressed as ml kg^{-1} min^{-1}. This doesn't mean you have to reach your maximum during a run - quite the contrary. It's enough that your speed exceeds 6 km/h and duration exceeds 12 minutes.

Once you've finished running, you'll be given your RI plus personal feedback. This feedback advises how your performance relates to other users in your reference group. To determine reference group, we'll use **gender** and **age** information.[1]

4   Validation

Running Index was first introduced in 2005 and later updated in 2013. As a result, validation studies cited here have been conducted with the 1st algorithm version instead of the latest one.

A study conducted in 2005 compared RI and treadmill test three times during a 12-week follow-up period.[2] Results (N = 13) showed that RI at 60% workload (39 ± 6; 41 ± 6; 42 ± 6) and 75% workload (41 ± 7; 41 ± 5; 42 ± 6) level was similar to VO2max determined on treadmill tests (42 ± 6; 44 ± 7; 43 ± 7 ml kg^{-1} min^{-1}). Furthermore, RI and VO2max demonstrated medium to strong correlation coefficients at all time points at both 60% workload (r = 0.85; 0.66; 0.67) and 75% workload (r = 0.85; 0.86; 0.83) levels.

In a second study (N = 12), RI correlated strongly with treadmill derived VO2max (r = 0.85–0.90).[3] Third study (N = 47) showed that RI may be underestimated if measured indoors with uncalibrated foot pod acting as a speed sensor (RI = 50 ± 8 vs. VO2max = 55 ± 7 ml kg^{-1} min^{-1}).[4] There was, again, significant correlation between RI and VO2max (r = 0.60; p < 0.001) and RI and 12-minute time trial test (r = 0.71; p < 0.001).

5   Benefits

Running Index is a simple way to determine your running fitness on every run. Because it's so simple, you'll quickly notice that you've accumulated a large running database. Benefits of RI:
- Easy to obtain as each run generates RI.
- Allows tracking over time.
- Enables comparison within reference group.
- Prediction of future performance.

As mentioned, the reference group is defined by age and gender. Future performance is predicted via race time estimates (see Fig. 1). Please note that actual race performance is determined by several factors, as discussed in the next section.

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6   Limitations

Running Index estimates your running performance with one number, that is VO2max. This is a simplification of reality. Running performance is determined by VO2max, anaerobic threshold and running economy. However, it's impossible to analyze the influence of these factors independently without access to laboratory-grade instruments, such as oxygen gas analyzer. However, training is likely to improve all these factors and your RI also.

Running Index is determined at every run; therefore, it must work with a limited data set - which is often gathered at submaximal performance level. The goal, however, is to predict maximal performance. To do this, we supplement exercise data with your resting and maximal heart rate information. Consequently, it's crucial that these numbers are set as correctly as possible.

Race time estimates are based on the general relation between distance and average speed that can be sustained over that distance. Sustainable speed is affected by many factors, some of which cannot be deduced from RI. Optimal race performance requires optimal preparation, such as reduced training load prior to race, as well as proper sleeping and eating. Varying race conditions such as racecourse and weather may also compromise performance. The ability to resist fatigue is the final piece in determining performance on the race day. Thus, race time estimates should be regarded as good guidelines rather than accurate predictions.

Although RI algorithm can filter out small stops and irregularities, the most repeatable results are achieved during longer runs (> 30 min) and at a steady pace.

7   Patents

Polar Running Index is protected by the following patents:
US2007082789, EP1795128

8   References

1. Shvartz, E., & Reibold, R., C. Aerobic Fitness Norms for Males and Females Aged 6 to 75 Years: A Review. *Aviation, Space, and Environmental Medicine.* **61**(1), 3–11 (1990).
2. Niva, A., Nissilä, J., Pullinen, T., Juuti, R. & Kinnunen, H. Heart rate response to steady state running reflects aerobic fitness and running economy. *11th Annual Congress of the ECSS*, Lausanne, Switzerland, July 3–8, 2006. Based on master's thesis by Juuti, R. University of Jyväskylä (2005). Available in Finnish from URL: https://jyx.jyu.fi/handle/123456789/19929,
3. Kinnunen, H., Parviainen, J. & Kaikkonen, H. *National sports medicine conference*. Helsinki, 2008. Based on master's thesis by Parviainen, J. University of Jyväskylä (2007). Available in Finnish from URL: https://jyx.jyu.fi/handle/123456789/25549
4. Cardinale, M., Jackson, A., Nissilä, J., Niva, A. & Kinnunen, H. Comparisons between a novel running Index and running performance measures in well-trained runners. *Med. Sci. Sports Exerc.* **39**, Supplement 5. 1415 (2007).

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Running Index report ❶

◀ | ▶   February - April 2021

Month **3 months** Custom period

Running ✖ | Road running ✖ | ▼

Progress chart

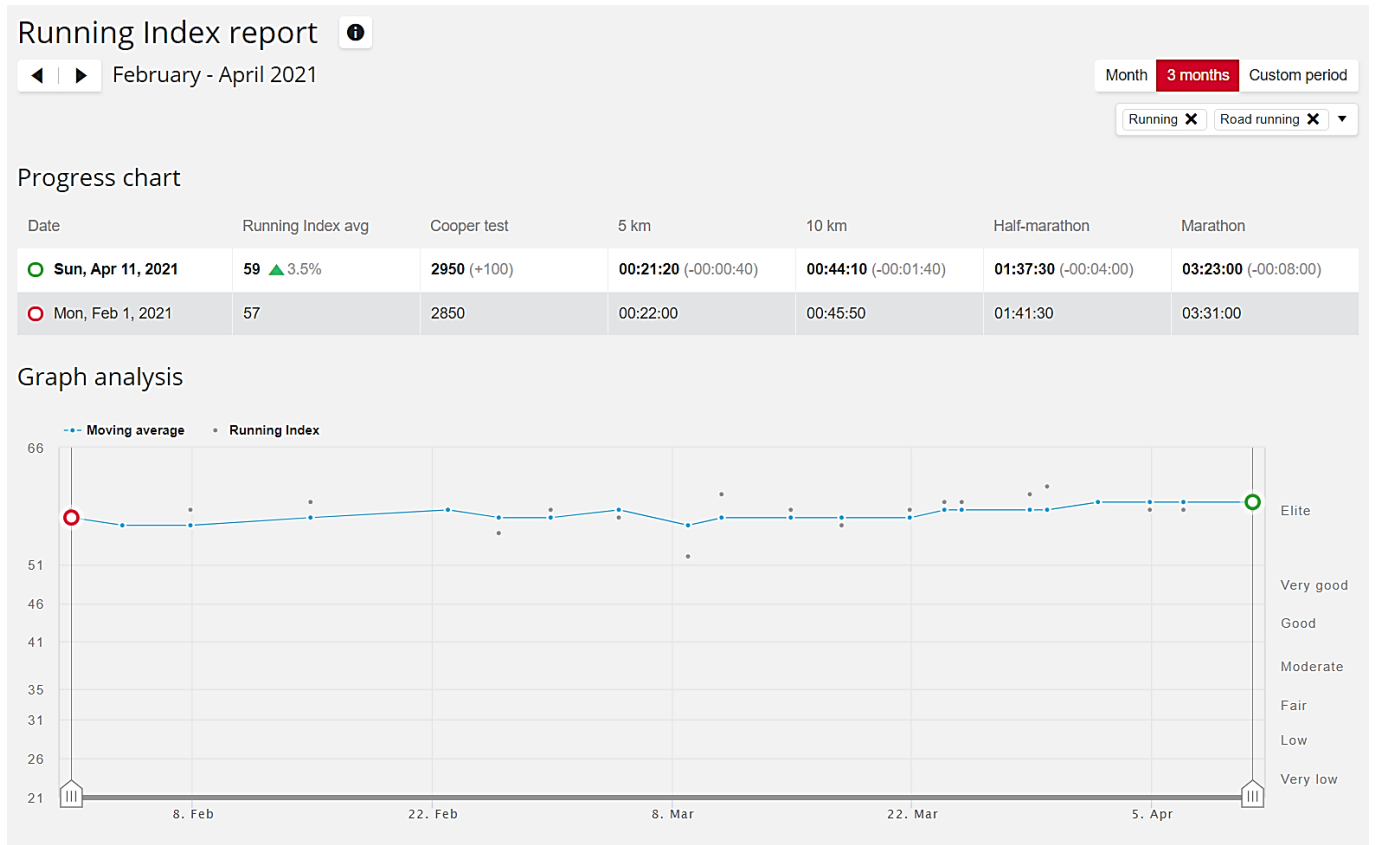| Date	Running Index avg	Cooper test	5 km	10 km	Half-marathon	Marathon
⭕ **Sun, Apr 11, 2021**	**59** ▲3.5%	**2950** (+100)	**00:21:20** (-00:00:40)	**00:44:10** (-00:01:40)	**01:37:30** (-00:04:00)	**03:23:00** (-00:08:00)
⭕ Mon, Feb 1, 2021	57	2850	00:22:00	00:45:50	01:41:30	03:31:00

Graph analysis

Figure 1. Example of Running Index report from Polar Flow service. *Top-right corner:* user selects observation period (currently 3 months). Below is a Progress chart, showing the first and last sample during the observation period. Graph chart displays values for each run (grey dots) and a blue trendline. *Left axis* displays Running Index and *right axis* fitness level in relation to reference group.