Polar Orthostatic Test

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Content

1 Introduction

The orthostatic test has a historical background in medical sciences, where it has been used to detect autonomic nervous system functions in various diseases. In sports, this test was introduced over 30 years ago and not long after became a part of many Polar products.[1]

The test is based on changes in heart rate (HR) and heart rate variability (HRV) and reflects cardiac autonomic modulation. It involves the measurement of HR and HRV during supine rest, active standing up, and quiet standing.

During supine rest, HR is low and HRV high because cardiac parasympathetic modulation is dominant. When standing up, there is a temporary reduction in blood pressure and a rapid withdrawal of parasympathetic modulation together with an increase in sympathetic outflow, resulting in an increase in HR shortly after standing up. The first 1-2 minutes after standing up are characterized by an increase in diastolic blood pressure, a sympathetic HR increase, and HRV decrease.

Over the years, Polar has developed and improved the way of taking an orthostatic test with wearables such as sport watches and heart rate monitors. Today, Orthostatic Test is part of Polar's Smart Coaching suite of features. This document describes the content and validity of current Orthostatic Test in Polar offerings.

2 Why measure

Heart rate and heart rate variability measured during the orthostatic test are good indicators of disturbances in the autonomic nervous system. Several studies have previously reported changes in HR and HRV during training overload, sleep deprivation, altitude or heat exposure, high mental and/or social stress, and during disease. HRV measures are, therefore, very helpful to assess the training readiness of an athlete, as they factor in all the challenges athletes face in their daily life, including stress from training and stress from other aspects outside training. Consequently, the purpose of the orthostatic test is to offer a way to monitor and understand how the body responds to training and other stressors in daily life. Hence, this test is a highly valuable tool to help determine the optimal training volume.

3 How Polar measures

Polar's Orthostatic Test feature records RR interval data beat by beat during the testing procedure. RR interval recordings require the use of a chest strap heart rate monitor or a watch that supports wrist-ECG measurements. Current optical beat to beat interval recordings cannot reliably detect the physiological changes in blood pressure and consequently, the beat to beat intervals occurring after postural changes.

Once RR interval data is recorded and before calculating final the results, errors and extra beats are eliminated. The resulting time series is generally called NN interval time series, i.e. from normal to normal heartbeats. When too many rejected RR intervals occur, the test is interrupted and the watch displays a warning and emits an alarm sound to notify the user.

The test result is based on changes in the NN parameters compared to the normal range. The normal range for each individual user is determined based on the calculation of the average of each parameter presented in Table 1.

Table 1. Parameters calculated from the filtered RR interval data.

	DESCRIPTION	TIME OF CALCULATION
1) $AVNN_{supine}$	Average NN while lying down	60-120 sec.
2) NN_{min}	The shortest NN following standing up	121-150 sec. (1-30 sec. after standing up)

3) AVNN$_{stand}$	Average NN while standing	180-240 sec. (60-120 sec. after standing up)
4) RMSSD$_{supine}$	Square root of the mean squared difference of successive NN	60-120 sec.
5) RMSSD$_{stand}$	Square root of the mean squared difference of successive NN	180-240 sec. (60-120 sec. after standing up)

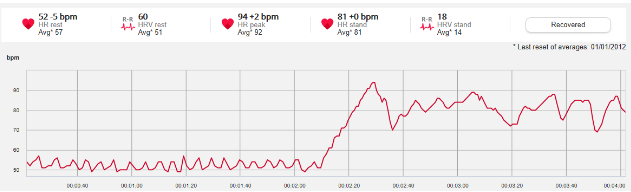

Figure 1. An example of an Orthostatic Test result as shown on Polar Flow website.

The test result shown in Figure 1 is a combination of numerical and visual feedback on the prevailing values compared to the user's usual values. On this visual representation, AVNN$_{supine}$, NN$_{min}$ and AVNN$_{stand}$ are converted to HR values (HR$_{supine}$, HR$_{peak}$, HR$_{stand}$) and presented in comparison with the corresponding average values (avg_HR$_{supine}$, avg_HR$_{peak}$, avg_HR$_{stand}$). For the first six tests the user takes, this corresponding average is calculated from the previous values and the new value. From the seventh test onwards, the average is calculated from the previous values not including the new value. The chart provides visual feedback on HR changes (lower, normal or higher) compared to the average. At any time, the user can reset the continuously updated average to start a new calculation of the average values. Resetting the average values will start a new testing period.

Also, the orthostatic test result includes the cardio recovery level, indicating whether the user is recovered or not recovered. Detailed information on this feature appears in Section 4.2 of the white paper on Training Load Pro and Recovery Pro. In brief, cardio recovery level calculations require at least three orthostatic tests completed in 28 days (two to establish the baseline and one to assess current condition). To estimate whether the user is recovered or not, it compares the latest orthostatic test result with the individual RMSSD baseline calculated from all measurements within 28 days. Depending on how much the RMSSD data from the latest orthostatic test deviates from the individual baseline, the cardio recovery level is automatically interpreted as recovered or not recovered.

4 Validity

Technical validity:

Previous studies demonstrated validity of R-R detection using Polar H10[2] and Polar H7 heart rate monitors[3,4]. Similarly, R-R detection from the wrist was successfully validated against Holter ECG. This method is described in more detail in Polar's white paper on Wrist-ECG (11).

The validity of HR and HRV measurements using Wrist-ECG during the orthostatic test was tested in 12 subjects against Polar H10. Two tests failed with wrist-ECG but not with H10. The mean absolute errors were 0.8 ms for RMSSD$_{supine}$ and 0.1 ms for RMSSD$_{stand}$. HR$_{supine}$ showed a mean absolute error of 0.1 bpm, HR$_{stand}$ 0.0 bpm and HR$_{peak}$ 4.7 bpm. The higher error in HR$_{peak}$ was mainly caused by the measurements observed in one participant, wh showed a 36 bpm higher HR$_{peak}$ with wrist-ECG compared to H10. The coefficients of variations were between 0,76 % (HR$_{stand}$) and 2,44 % HR$_{peak}$.

Physiological validity:

During periods of overreaching and overtraining, HRV recorded during orthostatic tests was considerably different than the baseline. [5–7] A training cycle guided by feedback from the cardio recovery level led to improvements in 5km running performance and VO$_{2max}$ similar to those achieved by following a professionally-designed training plans despite the lower training volume. It also led to greater improvements in running economy.[8]

5 Reliability and repeatability

HR and HRV measurements recorded with the Orthostatic Test feature were shown to be reproducible both at rest and after orthostatic challenge in healthy subjects[9] and in patients with a history of acute coronary syndrome.[10]

6 Advantages of use

With the Orthostatic Test, users can learn and understand how they're responding to the training load and other aspects of life. This may include factors that disturb their cardiac autonomic nervous system activity, such as sleep, stress, nutrition, environment, and more.

7 How to interpret values/results

By monitoring the difference between averages and new results, users can track the effects that an increased training load or other life aspects have on HR and HRV as their training season progresses. The test will show the newest peak, stand and rest values, and how much they differ from average values.

When one or more of these results fall below or rise above averages and don't normalize during recovery weeks with lower training loads, it's possible that the user is developing overtraining syndrome. However, HRV is only one indicator of overtraining. It is always recommended to monitor other changes, such as alterations in performance and general feelings of fatigue, as well.

Thanks to Polar's Cardio Recovery Level Smart Coaching algorithm, users can quickly receive an automatic interpretation of the orthostatic test and see if they are recovered or not.

The cardio recovery level result is an important input for Polar Recovery Pro. This feature, part of Polar Smart Coaching, assesses the cardio recovery level and the user's readiness for cardio training. It combines measured and subjective long-term recovery data with long-term training load (Cardio load) to provide daily training recommendations. Polar Recovery Pro is described in more detail in the Polar white paper on Training Load Pro and Recovery Pro (12,13).

8. Limitations

Normal NNI is required for HRV calculation. Therefore, individuals with abnormal RR intervals do not obtain a result. Other limitations include the necessity for highly standardized conditions to ensure comparability of results. Therefore, it is recommended to take always take the test in standardized conditions for the most reliable results.

The results provided by Orthostatic Test are highly individual, and the test is intended for continuous use. When measurements are not taken regularly, interpreting results becomes challenging.

9. Patents

US 8,082,030, European patent EP1852062 (validated in Germany, France, and Great Britain) and Finnish patent FI119618.

10. References

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