The HRV of the Ring – Comparison of nocturnal HR and HRV between the ŌURA ring and ECG

Kinnunen Hannu [1,2], Koskimäki Heli [1,3]

[1] ŌURA health, Oulu, Finland, [2] University of Oulu, Department of Electrical and Information Engineering, Finland, [3] University of Oulu, Biomimetics and Intelligent Systems Group, Finland

Abstract

Heart Rate Variability (HRV) has been widely used as a tool for managing training loads among athletes. The focus on this paper is to show how the OURA ring provides a highly accurate assessment of nocturnal Heart Rate (HR) and HRV. A test of 10 healthy adults demonstrated that the ŌURA Ring provided reliability as compared to ECG of (r = 0.999) and (r = 0.984) for HR and HRV, respectively. Knowing how crucial role assessment of recovery has in athletic training, a most reliable and comfortable measurement of HRV is an important addition to the offering of the ŌURA ring.

Introduction

A healthy heart's beating shows remarkable variation among the time intervals between heartbeats. Heart rate variability (HRV) consists of periodic and aperiodic changes in the duration of the cardiac cycle, which have both clinical and practical relevance. The clinical relevance was discovered with an observation that fetal distress was preceded by alterations in heart beat intervals before a respective change occurred in heart rate itself (2). Lack of HRV is also associated with higher cardiovascular mortality. Overall, High HRV is an indication of cardiovascular and autonomic health as well as general fitness.

In practical use, HRV is a biofeedback tool for improved relaxation, and an indicator of an athlete's recovery status and readiness to train. Typically when a person is under physical or mental stress, parasympathetic activity decreases and sympathetic activity increases. As a result, heart rate increases and HRV decreases. Relaxation and recovery are particularly reflected in increased high-frequency component of HRV. Sometimes HRV reacts earlier than HR, which makes it a particularly sensitive measurement. HRV is affected by a number of internal and external factors, such as age, hormones and lifestyle, and subsequently it is advisable to have your own established baseline as a reference. HRV tends to decrease with age. It also decreases when HR increases. At a given HR, women typically have a higher HRV than men.

In order to make HRV readings comparable to each other, it is particularly important to standardize the measurement with regards to the time of the day, prior activities and external stressors including ambient temperature, noise and presence of other people. Subsequently, nocturnal measurement provides an excellent measurement window. In order to get long term data there is a strong need for a comfortable measurement that does not disturb your rest, since state of the art HRV measurement devices are not comfortable and are not suitable for continuous use.

The golden standard method to determine HRV is via electrocardiogram (ECG) which requires a good skin contact via adhesive pads attached on skin (electrodes). The QRS complex of the ECG represents the electrical activation that initiates the contraction of the heart. The time between the initiations of succeeding heart beats is called the R-R interval (Figure 1). Each contraction of the heart results in blood volume pulse which propagates in blood circulation. Photoplethysmographic (PPG) signal arises from blood volume pulse in the periphery.
The ŌURA ring sits on user's finger and determines inter-beat-intervals (IBI) from PPG using invisible infrared light at a sample rate of 250 Hz. Studies comparing HRV parameters obtained by PPG and ECG have generally reported good agreement, particularly measurements done at night, but they have illustrated higher variability in PPG derived beat intervals particularly in high frequency parameters (4). PPG has smoother signal characteristics than ECG, and the signal waveform also varies depending on heart contraction force and arterial stiffness; all these factors increase the variability in the IBI data.

Several different HRV parameters are used in research and practical applications. The methodology of HRV is well presented in the Task Force committee report (2). The most commonly used parameter is rMSSD, a time domain parameter which is an estimate of short-term components of HRV and mostly reflects the parasympathetic autonomic nervous system activity. In research use, 5 minutes has become a standard duration for short-term measurements since shorter duration tend to give unstable results.

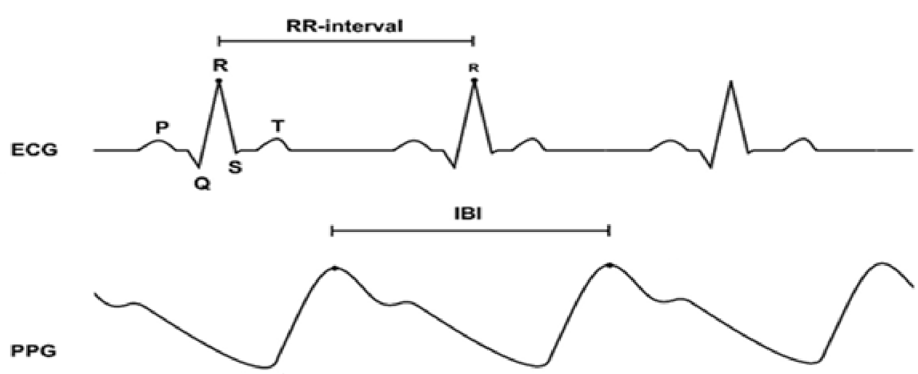

Figure 1. Schematic illustration of ECG and PPG signals over three heart cycles. One RR-interval and the corresponding IBI (inter-beat-interval) are marked with horizontal bars.

The ŌURA ring provides user with a very comfortable user experience and scientifically validated sleep quality metrics. It also handles several important factors that explain your Readiness to perform in daily life, many of which are partially determined by nocturnal HR and HRV. The sleep metrics of the ŌURA ring were successfully validated by Stanford Research Institute Center for Health and Sciences (7), yet the accuracy of nocturnal HR and HRV have not yet been published. Due to high wearing comfort, the ring would be a promising tool for long-term follow-up of recovery metrics.

The target of this study was to quantify the accuracy of the HR and beat-to-beat HRV measurement of the ŌURA ring. Since ECG based HRV is the state of the art method in the field, the values provided by the ŌURA ring were compared to the R-R intervals obtained from the ECG in healthy individuals at night. The HRV numbers provided by the ŌURA ring have been compensated for the additional variance found in PPG based IBI data.

Methods

We measured nocturnal IBI data with the ŌURA ring (Oura Health Ltd, Oulu, Finland) and simultaneous R-R interval data with Faros 360 ECG device (Mega Electronics, Kuopio, Finland) in 10 healthy individuals (3 female, 7 male). All subjects had the ŌURA ring on both hands, thus resulting in 20 nightly recordings for analysis.

The ŌURA ring labels each IBI as normal or abnormal. Each IBI was included for the calculation only if 8 consecutive IBI values had been labeled as normal. We determined heart rate HR and HRV for each 5-min sequence of the night ($HR_{5min\_ŌURA}$ and $rMSSD_{5min\_ŌURA}$) as well as nightly averages ($HR_{avg\_ŌURA}$ and $rMSSD_{avg\_ŌURA}$). Each 5-min sample was calculated only if more than 50% and 30% of the intervals were accepted by this criteria for HR and rMSSD, respectively.

Kubios HRV software was used to calculate ECG based reference values for the entire night (HR_{avg_ECG} and $rMSSD_{avg\_ECG}$). In Kubios software, an automatic filter with medium setting was used to detect and exclude potentially abnormal R-R intervals from analysis. For the 5-min data, the same Matlab script was used to obtain reference numbers for both PPG and ECG (HR_{5min_ECG} and $rMSSD_{5min\_ECG}$). In 5 min data the synchrony of IBI data and RR data was ensured within 5 seconds.

The agreement between the methods was assessed by correlation analysis.

Results

Nightly average for HR and HRV

The comparison (scatter plot) between HR $_{avg\_ŌURA}$ and HR $_{avg\_ECG}$ is presented in Figure 2, and the comparison (scatter plot) between rMSSD$_{avg_ŌURA}$ and rMSSD$_{avg_ECG}$ in Figure 3.

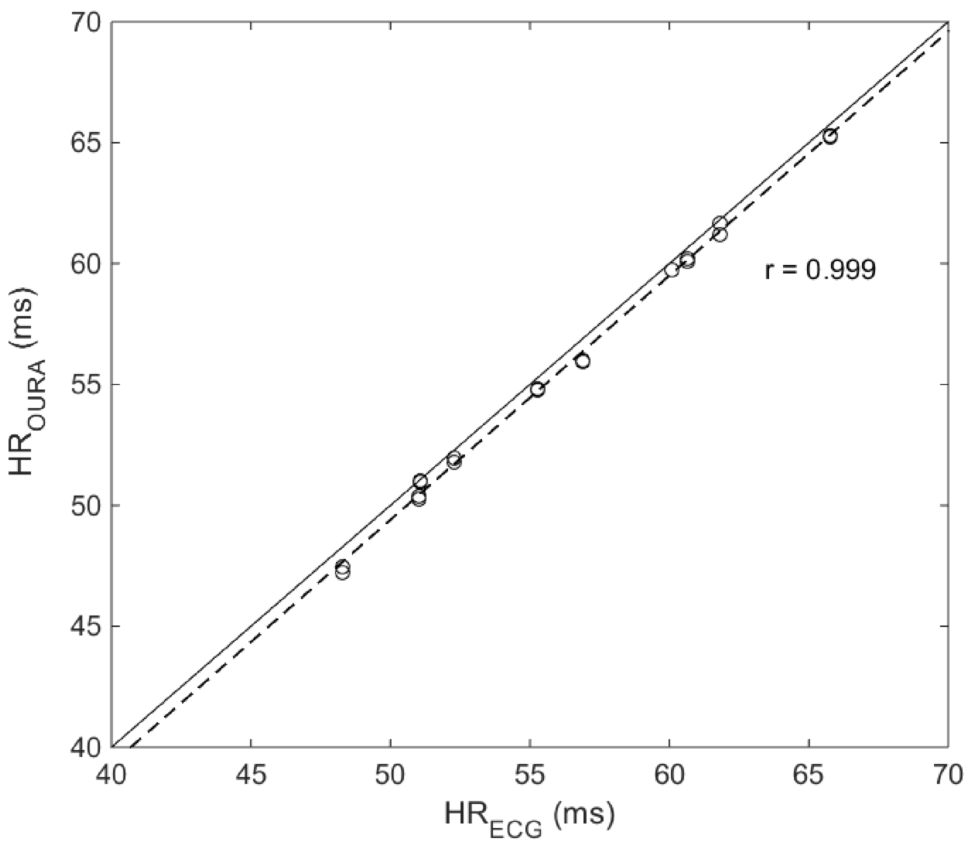

Figure 2. Scatter plot on HR derived from ECG by Kubios software (HR$_{ECG}$) and the corresponding value from the ŌURA ring (HR$_{OURA}$) in the sample of 10 subjects, all wearing the ŌURA ring on both hands. Coefficient of correlation was 0.999 with a bias of -0.53 bpm by the ŌURA ring.

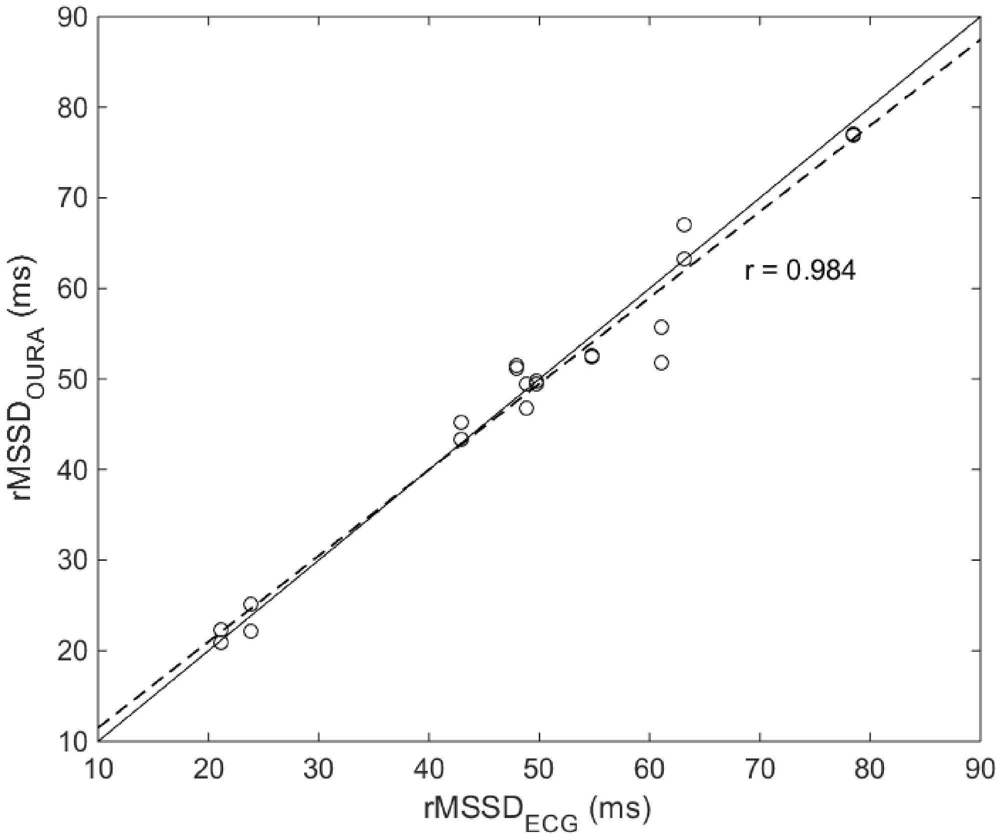

Figure 3. Scatter plot on HRV derived from ECG by Kubios software ($rMSSD_{ECG}$) and the corresponding value from the ŌURA ring ($rMSSD_{OURA}$) $MSSD_{add}$) in the development sample of 10 subjects, all wearing an ŌURA ring in both hands. Mean absolute deviation was 2.1 ms.

5-min sequences of HR and HRV

95±7% of the 5-min sequences of the entire night had enough qualitative IBI data to be included for HR analysis. Within-subject correlation between HR_{5min_OURA} and HR_{5min_ECG} was 0.96 ± 0.02 (mean ± sd).

90±13% of the 5-min sequences of the entire night had enough qualitative IBI data to be included for HRV analysis. Within-subject correlation between $rMSSD_{5min\_OURA}$ and $rMSSD_{5min\_ECG}$ was 0.84 ± 0.15 (mean ± sd).

Discussion

Significance of the present findings

In this study close to perfect agreement (r = 0.999) was found between the nocturnal HR determined by the ŌURA ring and that determined from ECG by Kubios Software. Also strong agreement (r = 0.984) was found in rMSSD.

The reliability of the HR measurement was further confirmed in the short term (5 min) data. Among the 20 recordings (in our 10 subjects, both hands from each), the correlation between the methods was very high (r = 0.96 ± 0.02). Regarding rMSSD, the corresponding results also showed high consistency between the methods (r = 0.84 ± 0.15).

As the ŌURA ring provides an unpreceded wearing comfort for the measurement of nocturnal HR and HRV, the present confirmation about the reliability of the HR and HRV numbers is very welcome for long term follow-up studies. The limitation with the present study is that it only included healthy subjects whose rMSSD was in the range of 20 - 100 ms - validity among subjects who have very low HRV needs to be studied separately. The present results regarding rMSSD, the most commonly used time domain parameter of HRV, also prompt a question if ŌURA ring IBI data would also be suitable for frequency domain parameters of HRV.

During most active periods of night, or if signal quality was poor as was the case in two subjects due to a loose ring, certain 5-min sequences did not contain enough good quality IBI data and they were excluded from further analysis. On average, the excluded amount was very small, 5% and 10% of the night for HR and rMSSD, respectively. However, in the two cases the excluded part of night represented higher or lower than average HRV. As all 10 subjects had two different rings for each night, these differences that can be detected in Figure 3. This observation reminds of the importance of having a properly fitting ring for best signal quality.

Where to get guidance how to improve HRV

Comfortable measurement and easy access to long-term HR and HRV data measured within normal life also invites product manufacturers and researchers to provide guidance how to improve ability to recover, for example if someone’s HRV would indicate prolonged stress. Intensive exercise acutely reduces HRV but regular physical exercise significantly increases it in the long term. Exercise, like a lot of other things, is dose dependent. In other words, too much can lead to overtraining and negative health consequences. Smoking and alcohol consumption reduce HRV. Antidepressant medicine has been shown to seriously reduce HRV.

Resting HR is a traditional way to monitor stress levels. Resting heart rate can be expected to elevate as a response to internal or external stressors, such as heat, a heavy meal, alcohol intake, late-day exercise and so on. However, acute fatigue also lowers resting heart rate that is sometimes experienced as a very low resting heart rate at sleep onset. Gradually lowered resting HR is also a sign of training response, typically associating with increased fitness.

However, it is important to check that your lowered resting HR is not indicating accumulating fatigue.

Individual training guidance based on HRV has shown promising results in recreational endurance training (2, 3, 6). High HRV compared to your earlier values measured daily during standardized situation seems to be an indication of readiness to train for improved fitness. Nocturnal measurement provides a natural, standardized way to obtain a daily measurement of HRV. It also seems that personal level of HRV also predicts training response of several weeks of training among recreational endurance athletes: If you have high HRV, your body can be expected to respond positively to high intensity training (1, 5). If you have low HRV, during several weeks of endurance training the expected response to high volume of low intensity training is highly positive while the expected response to high intensity training is small (6).

Since HRV is a very sensitive measure and requires interpretation, it is advisable to check for other factors of health, prior physical activity and other factors that affect readiness to train, including traveling. Among elite athletes HRV may also saturate in connection with low heart rates which needs to be taken into account when interpreting long term data (3). In female athletes, menstrual cycle phase can also be taken into account in training guidance as a separate factor, and also because it affects resting HR and HRV.

To conclude, the ŌURA ring characterizes your sleep and also summarizes factors behind your mental and physical Readiness. The nocturnal resting HR and HRV numbers measured by the ring represent similar values to those derived from the ECG. Knowing how crucial role assessment of recovery has in athletic training, a most reliable and comfortable measurement of HRV is an important addition to the offering of the ŌURA ring.

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