Validation of the LifeQ solution for measuring Heart Rate Variability

Version 2.0

Introduction

Heart rate variability (HRV), also known as cycle length variability or RR variability, is a physiological phenomenon and is the result of a number of different inputs, such as thermoregulation, physical activity, stress and hormonal level.

A modified (usually reduced) HRV has been shown to be associated with a range of conditions, including congestive heart failure, diabetic neuropathy and sudden infant death syndrome (SIDS).

A number of methods exist to measure HRV, for e.g. electrocardiogram (ECG), blood pressure measurement, ballistocardiogram or photoplethysmograph (PPG), of which ECG remains the superior method to date. RR variability refers to variability in length of subsequent "QRS" complexes (from ECG data) and pulse peaks (from PPG data). After initial calculations, intervals are referred to as NN-intervals.

In this study, HRV, as quantified using wrist-band PPG measurements (collected at 50 Hz) from a group of individuals, will be compared to ECG measurements (collected at 1000 Hz) from the same group. The goal of this comparison is to validate LifeQ's heart rate variability solution by comparing it to chest-strap ECG derived HRV.

LifeQ's body monitoring module measures HRV using an optical sensor, comprising of five light emitting diodes and a photo sensor combined with an accelerometer.

The accuracy of these optical measurements are typically influenced by movement, the level of perfusion (blood delivery to the capilary bed) and the melanin content of the skin.

Methods

Each participant wore a LifeQ enabled device and an ECG chest strap. Tests were done under ideal, resting conditions (i.e. with no movement). Currently, our HRV solution does not account for movement during testing, however this is also diagnostically irrelevant.

The sample size for this study was 24 individuals (males and females aged 25-41), including two with low perfusion and two with high melanin content (dark skin).

Data was collected from all individuals for both devices and analyzed to obtain beat-to-beat (NN-intervals). Statistical analysis was performed on both PPG and ECG datasets, namely determining the mean of NN-intervals (AVNN) and the standard deviation of NN-intervals (SDNN), as well as a correlation between the datasets. The outcome of these analyses are presented below.

Key findings

We show results from statistical analysis performed on data from I) 120 continuous NN-interval measurements for 4 participants and II) 350 continuous NN-interval measurements for 1 participant.

Additionally, the data of all 24 participants were pooled and a correlation between ECG and PPG derived HRV is presented.

Comparison on an individual level

Recorded NN-interval data presented here are from 4 participants representing a i) male, ii) female, iii) male with low perfusion and iv) dark-skinned male.

Tables 1-4 summarizes the statistical data of comparison criteria for both signals.

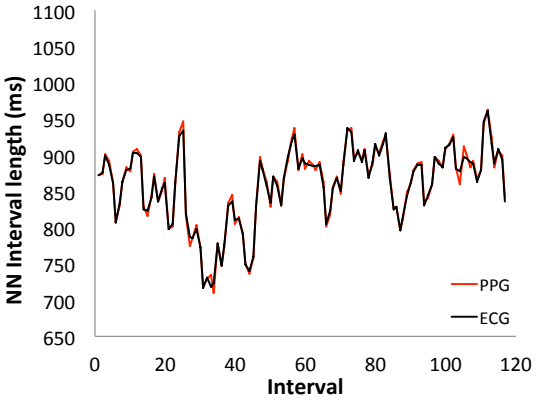


Fig 1. Comparison of NN interval length as measured by ECG and LifeQ device (PPG) for a male.

Table 1. Intersignal statistics of participant 1.

	ECG (ms)	PPG (ms)
Mean of NN	859	860
SD of NN	52	53

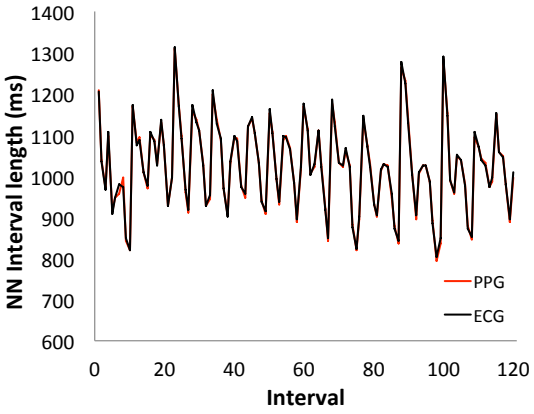


Fig 2. Comparison of NN interval length as measured by ECG and LifeQ device (PPG) for a female.

Table 2. Intersignal statistics of participant 2.

	ECG (ms)	PPG (ms)
Mean of NN	1025	1024
SD of NN	105	105

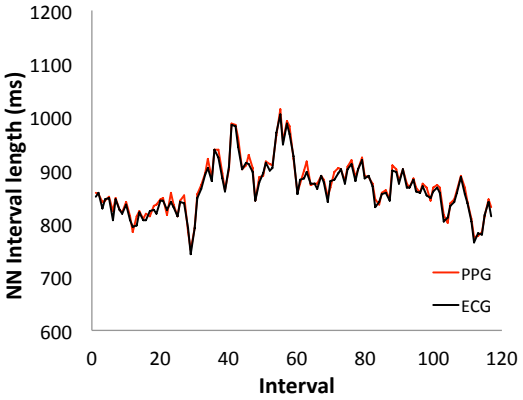


Fig 3. Comparison of NN interval length as measured by ECG and LifeQ device (PPG) for a male with low perfusion.

Table 3. Intersignal statistics of participant 3.

	ECG (ms)	PPG (ms)
Mean of NN	865	870
SD of NN	48	49

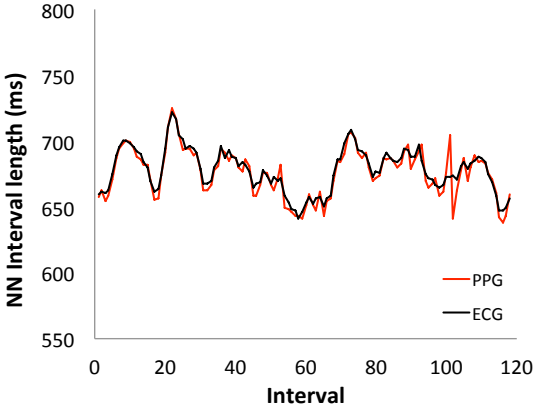


Fig 4. Comparison of NN interval length as measured by ECG and LifeQ device (PPG) for a male with dark skin.

Table 4. Intersignal statistics of participant 4.

	ECG (ms)	PPG (ms)
Mean of NN	678	676
SD of NN	16	18

Continuous NN-interval measurement

Fig. 5 and Table 5 shows the comparison of data over a period of 350 continuously measured NN-interval measurements and represents the concept of a continuous and user-defined period of data capturing.

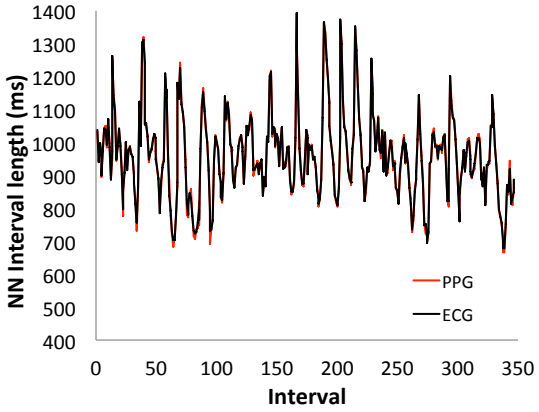


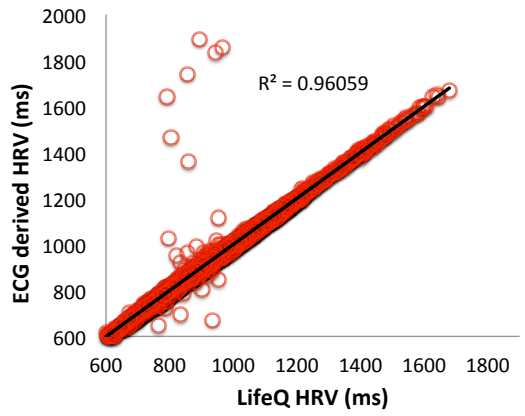
Fig 5. Comparison of NN interval length as measured by ECG and LifeQ device (PPG).

Table 5. Intersignal statistics of participant 5.

	ECG (ms)	PPG (ms)
Mean of NN	959	959
SD of NN	128	91

Comparing pooled data

Fig. 6 depicts the correlation between data from all 24 individual participants.



The NN-intervals presented in Figs. 1-7 are the full, raw output from the devices, aligned to enable comparison of the output. Even with the most severe outliers included, the data has an R^2 value of 0.961 (Fig. 6).

However, these outliers represent only 11 datapoints out of a total of 4925 (0.22 %). With these outliers removed, the R^2 value increases to 0.997 (Fig. 7). Note: outliers were not from individuals with low perfusion, nor from high melanin content individuals. The average percentage error of the pooled data is 0.695% with a standard deviation of 0.87%.

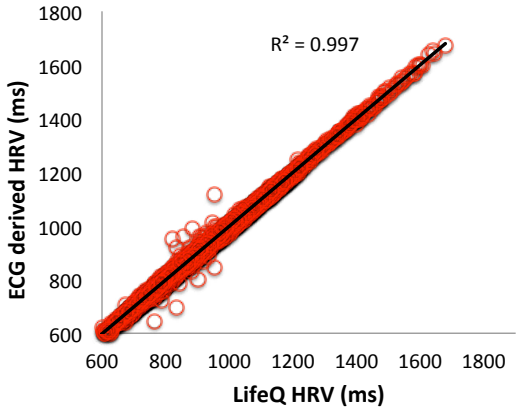


Fig. 7. Scatterplot of NN-intervals for ECG vs LifeQ device of pooled data, with the most severe outliers removed.

The data shown in Figs 1-5 and Tables 1-5, including the high correlation (R=0.9985) and low percentage error (0.695%) between data from the LifeQ device and the ECG chest strap (Fig. 7) is evidence of the accuracy of the LifeQ device in measuring HRV.

The raw and unfiltered data presented here allows for the identification and removal of outliers in the data. Subsequently, this enables the calculation of relevant HRV metrics such as high- and low-frequency ratios, well within acceptable error ranges.