Validation of Oxa's HR and HRV algorithms using the gold-standard software Kubios

A product evaluation project

Abstract This project aimed to validate the accuracy and reliability of the heart rate (HR) and heart rate variability (HRV) algorithms used in the Oxa product. Oxa is a smart-garment that offers, among others, real-time recording and analysis of heart activity. The study compared the outcomes of Oxa to the gold-standard HRV software, Kubios, to ensure the validity of the algorithms. Data collection was conducted on a voluntary basis with participants from the Nanoleq employee pool. The results showed a strong correlation between the HR and HRV values obtained from Oxa and Kubios, indicating the reliability of the algorithms used by Oxa.

Introduction

The purpose of this project was to evaluate the performance of the HR and HRV algorithms used by Oxa. Oxa provides high-quality recording and analysis of heart activity, which can be used for assessing the relaxation/stress of an individual. The HR (represented by the RR interval) and HRV, measured by the root-mean-square of successive differences between normal heartbeats (RMSSD), are important indicators of vagal tone. For a meaningful evaluation of heart rate variables, accurate detection of heartbeats is essential. To validate algorithms developed for the Oxa platform, data collected with Oxa was compared to Kubios, a widely recognized HRV software, with gold standard status.

Method

A total of 15 volunteers from the Nanoleq employee pool participated in this study. They performed a 24-minute exercise consisting of seven different breathing rates, ranging from 4 to 7.5 breaths per minute (bpm) with 0.5bpm increments. The Oxa smart-garment was used to record respiratory and ECG signals during the exercise. The participants followed a visual and auditory guide for breathing pacing. The recorded data was analyzed using Kubios and the Oxa python library to extract RR intervals and RMSSD. The outcomes from both tools were compared.

Results

The analysis of the data showed a high correlation between the mean RR intervals obtained from Kubios and Oxa for each participant (Table 1, Figure 1). The Pearson correlation coefficient was found to be 1.000 (Figure 2 A, rounded to 3 decimals), indicating a strong agreement between the two methods. The correlation analysis also revealed a strong relationship between the RMSSD values obtained from Kubios and Oxa, with an average Pearson correlation coefficient of 0.941. When converting the Kubios RMSSD to log scale, as suggested by the wide-spread HRV software solution EliteHRV, the Pearson correlation was 0.996 (Figure 2 B). The slight differences observed can be attributed to variations in calculating RMSSD. Overall, the results demonstrate the congruence between the HR and HRV outcomes from Oxa and Kubios.

Conclusion

This project successfully validated the HR and HRV algorithms used in the Oxa product by comparing them to the gold-standard software Kubios. The strong correlation between the HR and HRV values obtained from both tools indicates the reliability and accuracy of the algorithms used by Oxa. The results support the validity of Oxa in providing accurate HR and HRV.

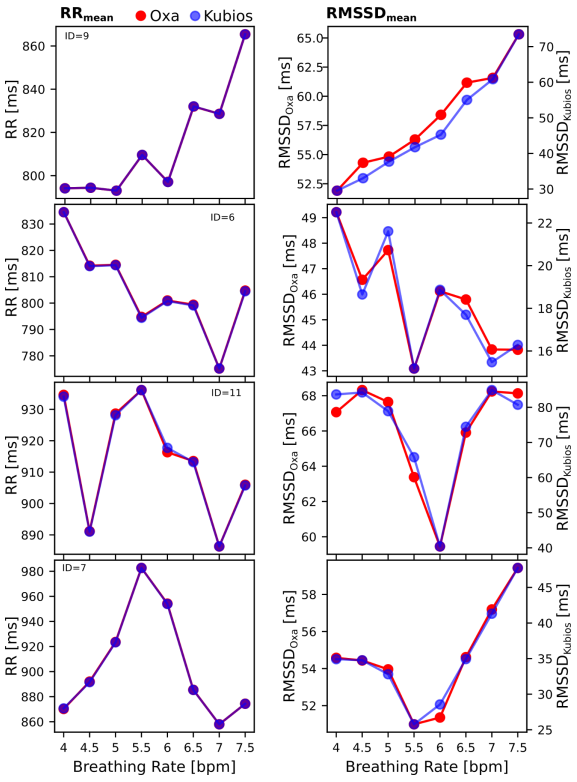

Figure 1: Illustration of the congruence between Kubios and Oxa for mean RR (left) and mean RMSSD (right) for 4 participants. The ID number (anonymized) of the participant is indicated in italic in the left plot. Data are shown as mean over all tested breathing rates. For RMSSD the primary axis indicates Oxa values and the secondary Kubios values. Red= Oxa, Blue= Kubios.

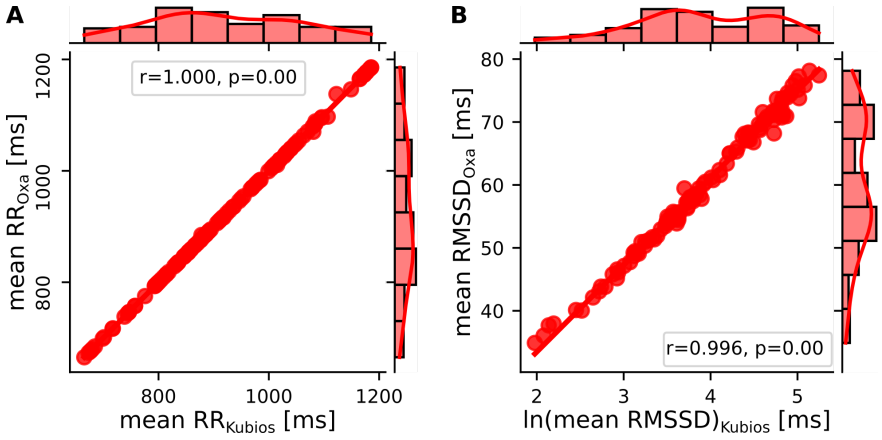

Figure 2: Pearson correlation between Kubios and Oxa for RR (A) and RMSSD (B), *for all assessed breathing segments*. The natural logarithm of the Kubios results is depicted in B. Pearson coefficient r (rounded to 3 decimals) and p value (rounded to 2 decimals) are given.

Table 1: Pearson correlation coefficient (r) between the analysis conducted in Kubios and Oxa for the two parameters RR and RMSSD, *for the averages per participant (ID)*.

ID	r_{RR}	r_{RMSSD}
1	0.999	0.981
2	1000	0.982
3	1000	0.996
4	0.996	0.934
5	1000	0.971
6	1000	0.981
7	1000	0.995
8	1000	0.941
9	1000	0.988
10	0.996	0.871
11	0.999	0.979
12	0.998	0.799
13	1000	0.909
14	1000	0.977
15	1000	0.946
mean±std	**0.999±0.0001**	**0.95±0.05**