

## Accuracy of Kubios HRV software respiratory rate estimation algorithms

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Respiratory rate (RESP) is one of the vital signs that is widely used in a range of clinical settings as well as in exercise monitoring. In addition, RESP can be used in heart rate variability (HRV) analysis, specifically to improve the accuracy of respiratory sinus arrhythmia (RSA) assessment. Respiration can be directly measured using various techniques, but RESP can also be indirectly estimated from electrocardiogram (ECG) or beat-to-beat interval (RR interval) recordings. In this paper, we have validated two RESP algorithms, which are available in a commercial HRV analysis software (Kubios HRV Premium, ver. 3.5). The algorithms were validated with resting HRV recordings from 262 participants and with maximal exercise test recordings from 123 participants. The true RESP was extracted from respiration measurement by counting the number of respiratory cycles within a time period. RESP was estimated using either both ECG (respiration-induced changes in ECG amplitude) and RR (respiration-induced changes in RR interval oscillations) features, or only the RR features. The observed correlation with true RESP was strong to moderate in resting HRV recordings ( $R = 0.892$  vs.  $R = 0.676$ ) and strong in exercise HRV recordings ( $R = 0.922$  vs.  $R = 0.881$ ), with higher correlations corresponding to the estimates that used both ECG and RR features in RESP estimation. Overall, the bias and accuracy of the algorithm which utilized both ECG and RR data for RESP estimation was better. The average bias of the RESP estimation algorithms was 0.025 Hz (0.021 Hz vs. 0.029 Hz), which equals to 1.5 breaths/min. The accuracy (error SD) of the RESP estimation algorithms was on average 0.071 Hz (0.062 Hz vs. 0.080 Hz) or 4.3 breaths/min. The algorithm that used both ECG and RR features in respiratory rate estimation performed better especially at high respiratory rates.

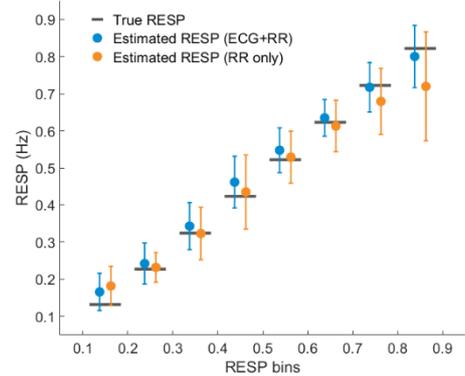


Figure: Accuracy of RESP estimates.