

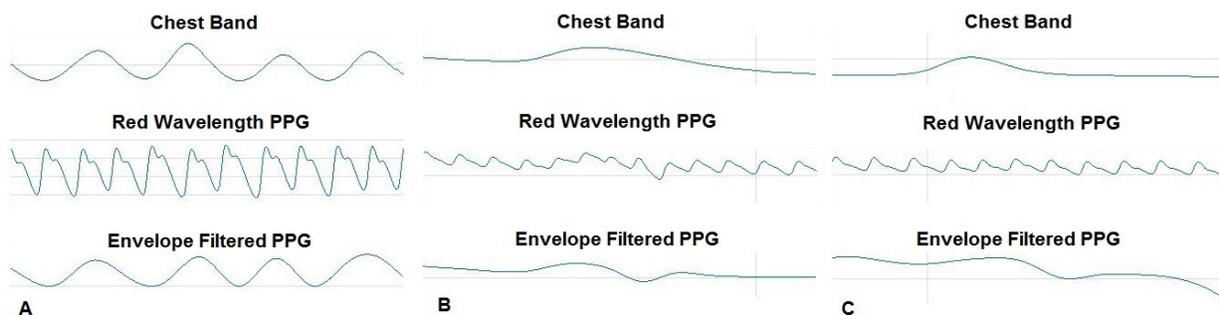
## Using Photoplethysmography to Detect Low Respiratory Rates

**Authors:** Sean Ermer B.S., Lara Brewer Ph.D, Joe Orr, Ph.D, Ken Johnson M.D, M.S.  
University of Utah

**Introduction:** Photoplethysmography (PPG) has been suggested numerous times as a method for detecting respiration in patients wearing a pulse oximeter. Though it's known that respiration produces measurable changes in the PPG waveforms, the exact mechanism of these changes is still debated; generally it is believed to be the result of both intrathoracic pressure changes from inspiration and expiration, and from a reduction in cardiac output [1]. We investigated the potential for using a PPG-based respiratory rate monitor at low respiratory rates.

**Methods:** With IRB approval, 26 healthy volunteers were recruited and administered target controlled infusions of remifentanyl (0.25-0.5 ng/mL) and Propofol (0.75 – 2 mcg/mL) in order to induce low respiratory rates. Subjects were instrumented with a pulse oximeter located on the finger and respiratory inductance plethysmography (RIP) bands which recorded data at 100 Hz. An envelope filter was used to obtain the baseline signal (related to respiration) from the PPG. The RIP band (as the reference respiratory rate signal) and the PPG signal were analyzed in Matlab R2016B (Mathworks, Natick, MA) in order to explore the potential for using PPG to monitor respiratory rate below 10 breaths per minute (BPM).

**Results:** Three different cases are presented in the figure below. The first represents the high respiratory rate scenario. The other two are both cases where the respiratory rate was less than six BPM.



**Figure 1:** **A:** Chest band, PPG, and filtered PPG signals for a respiratory rate of 20. As expected, the envelope of the PPG signal modulates in time with the chest band signal. **B:** Chest band, PPG, and envelope PPG signals for a respiratory rate of 5. A Large deflection in the envelope PPG signal occurs at the same time as the breath. **C:** Chest band, PPG, and envelope PPG signals for a respiratory rate of 5. The envelope PPG signal deviates out of sync with the chest band.

**Discussion:** The appearance of the ventilation-related change in the PPG signal at low respiratory rates is different from the appearance of the signal at high respiratory rates. This could be due to a number of reasons. Sympathetically mediated vasoconstriction is known to present in the PPG at large tidal volumes, which may be more pronounced at low respiratory rates. Additionally, there are a number of physiological changes unrelated to respiration that cause baseline fluctuations in the PPG. These may mask the true signal at low respiratory rates. Overall, a more advanced algorithm may be required to properly identify respiration at low respiratory rates as opposed to high ones.

[1] Meredith, D. J., D. Clifton, P. Charlton, J. Brooks, C. W. Pugh, and L. Tarassenko.

“Photoplethysmographic Derivation of Respiratory Rate: A Review of Relevant Physiology.” *Journal of Medical Engineering & Technology* 36, no. 1 (March 1, 2012): 1–7.  
doi:10.3109/03091902.2011.638965.