Calibration methods between pulse wave velocity and blood pressure with PPG morphology

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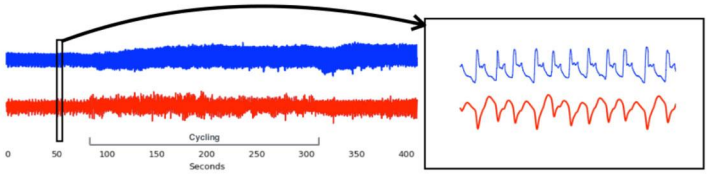
Background

Pulse arrival time is an indirect measure of pulse wave velocity (PWV). Pulse wave velocity is correlated with systolic blood pressure (SBP) and has been proposed as a surrogate method to track systolic blood pressure. The relationship is given by the Moens-Korteweg equation (on the right).

$$PWV = \sqrt{\frac{E_0 e^{\gamma BP} \cdot h}{2\rho \cdot r}} \qquad BP = \frac{1}{\gamma} ln(PWV) - \frac{ln(E_0 h)}{2\rho r \gamma}$$

E_0, h, ρ, r and γ can be assumed to stay relatively constant within a subject.
Thus, a linear calibration to estimate the parameters *A* and *B* in the linear relationship *SBP = A * ln(PWV) + B* would allow PWV-based SBP tracking.

While *B* can be predicted with a single calibration measurement, *A* requires a set of simultaneous SBP and PWV measurements to enable accurate calibration.



Proposal

The parameter γ is an expression of the responsiveness of PWV to changes in SBP, which is related to the ability of the blood vessel to increase in size (i.e. elasticity) in response to increasing pressure.

Measuring arterial elasticity directly is not possible, but the Age Index (AGI) has been proposed as a morphological characteristic of the blood pulse waveform (measured with photoplethysmography, PPG) that expresses the arterial elasticity. AGI is derived from the acceleration PPG (on the right) as: AGI = (b-c-d-e)/a

We propose that if the subject experiences a stressor that induces changes in blood pressure (e.g. physical exercise), the change in AGI will be proportional to the parameter γ.

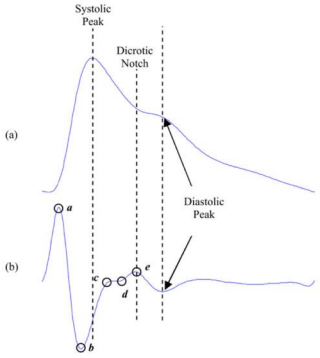
Method

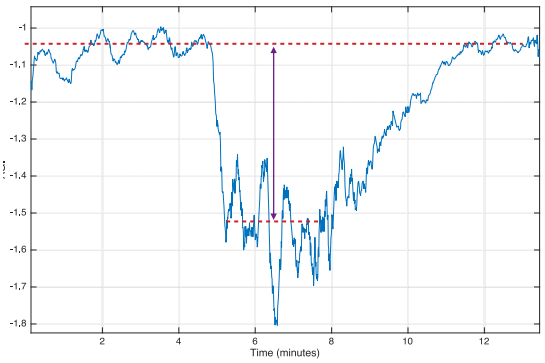
Data collection: 16 subjects performed cycling experiments (5 minutes cycling, 5 minutes rest, repeated 3 times). For each heart beat, the following measures were computed:
- **PWV** from ECG to finger PPG,
- **SBP** with a CNAP device (vascular unloading technique)
- **AGI** from the second derivate of the finger PPG.

Ground truth for A: After data cleaning, traditional linear calibration was performed by fitting PWV to SBP through *SBP = A * PWV + B*. All heart beats of a participant were used as samples in this model.

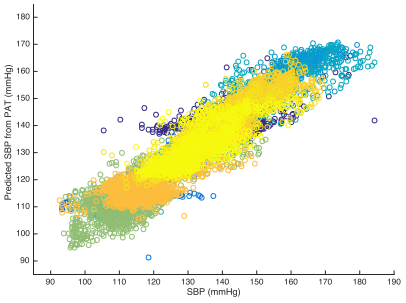
Predicting A with AGI: The change in AGI during cycling was computed as the standard deviation of AGI over the entire cycling/rest period. The parameters A were predicted using std(AGI) through linear regression per subject. A correlation of 0.84 is found between A and std(AGI).

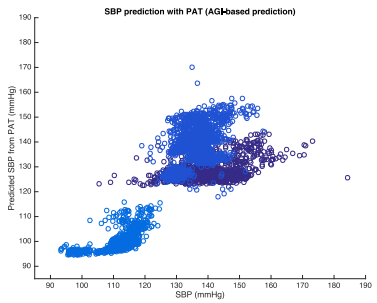
Performance evaluation: To test the performance, std(AGI) was used to predict A (A_{pred}). Then, a single baseline calibration point was taken where SBP_{base} and PWV_{base} was obtained for each subject. B was then calculated as: $B = SBP_{base} - A_{pred} * (\ln(PWV_{base})$





AGI-based calibration





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