Estimation of Pulse Arrival Time Using Impedance Plethysmogram from Body Composition Scales

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Arterial stiffness leads to the development of cardiovascular morbidity and mortality\(^1\).

Central (aortic) stiffness:
- elderly subjects,
- end-stage renal disease,
- hypertension,
- impaired glucose tolerance.

Peripheral (lower-limbs) stiffness:
- peripheral artery disease,
- diabetic peripheral neuropathy.

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Long-term periodic monitoring needed
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Available devices for PPW recording
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Illustration retrieved from http://www.atcormedical.com/
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Available devices for PPW recording:

- Operator dependent
- Results rely on the placement

Impedance plethysmography (IPG) to determine changing tissue volumes (e.g. blood)

\[ \Delta R = \rho \frac{l^2}{\Delta v} \]
Impedance plethysmography (IPG) to determine changing tissue volumes (e.g. blood).

ECG and IPG electrodes integrated into unobtrusive devices (e.g. bathroom scales)

Illustration retrieved from *OMRON HBF-510 Instruction Manual*
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The goal of this study is to demonstrate that PAT from the heart to the foot can be estimated using ECG and IPG recorded on the bathroom scales.

Body composition scales (Omron)

- ECG: wireless ECG transmitter (Biopac)
- IPG: electrical bioimpedance unit (Biopac)
- IPG: photoplethysmogram amplifier unit (Biopac)
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Illustration retrieved from OMRON HBF-510 Instruction Manual
Four healthy subjects (one woman)

Paced respiration (0.1 Hz) to cause hemodynamics changes
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Measurement cases

foot-to-foot

single-foot

Illustration retrieved from *OMRON HBF-510 Instruction Manual*
Four healthy subjects (one woman)

Paced respiration (0.1 Hz) to cause hemodynamics changes

Measurement cases

foot-to-foot

ground

single-foot

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Digital filtering

Synchronized ECG, IPG and PPG signals

Detection of R-waves and extraction of RR intervals

RR interval

Estimation of $T_{D1}$ within RR interval

Estimation of PAT

$T_R$

$T_{D1}$

1-D median filtering

Evaluation of relation
Detection of R-waves and extraction of RR intervals

Digital filtering

Synchronized ECG, IPG and PPG signals

ECG

IPG

PPG

RR interval

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$T_{R}$

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 Synchronized ECG, IPG and PPG signals

 ECG

 IPG

 PPG

 $T_R$

 $T_{D1}$
Signal Processing

Digital filtering
- ECG
- IPG
- PPG

Synchronized ECG, IPG and PPG signals

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Estimation of PAT
- $T_R$
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Evaluation of relation
Results:

Example of the signals

Foot-to-foot case

Single-foot case
Results:

Example of the estimated PAT

Foot-to-foot case

Single-foot case
Results:

Foot-to-foot case

Single-foot case
Results:

example of estimated PAT

Foot-to-foot case

Single-foot case
Foot-to-foot case

Single-foot case
Results: foot-to-foot vs. single-foot

Data represent mean ± SD
Results: foot-to-foot vs. single-foot

Data represent mean ± SD
Results:

Boxplot of the absolute values of PAT

Legend:
- Red: Single-foot IPG
- Blue: Foot-to-foot IPG
- Green: PPG
Results:

Boxplot of the absolute values of PAT.
Results:

Boxplot of the absolute values of PAT 12/14
Custom-made bioimpedance unit integrated into body composition scales
Conclusions

– PAT can be estimated by using IPG and ECG sensors, which are integrated into body composition scales;
– PAT evaluated by the method introduced in this study correlates with PPG-based PAT;
– single-foot and foot-to-foot $PAT_{IPG}$ slightly differs.

Future directions

– testing of the custom-made system;
– development of the algorithm for the calculation of PAT;
– a wider group of subjects with different health status.
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Thank you for your attention