A database for developing pulse wave analysis algorithms

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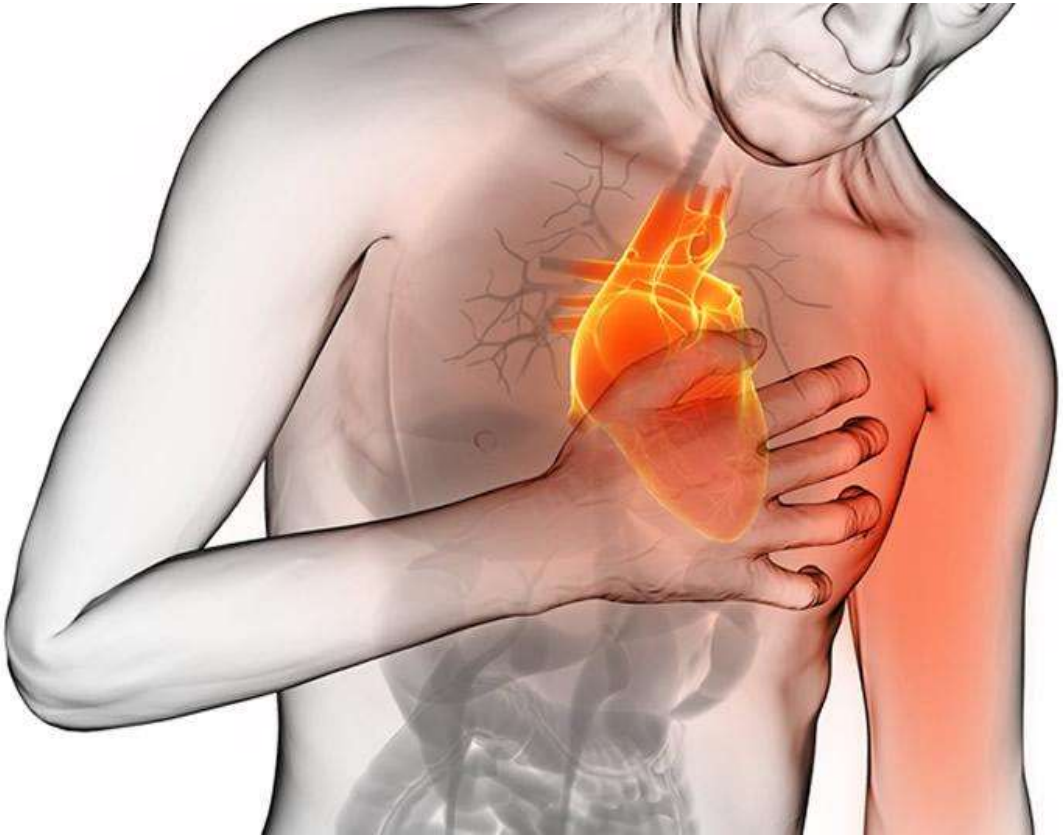
Presentation originally given at BioMedEng18 Conference, Imperial College, London, 7th Sept 2018

Every 10 mins in UK:

3 deaths

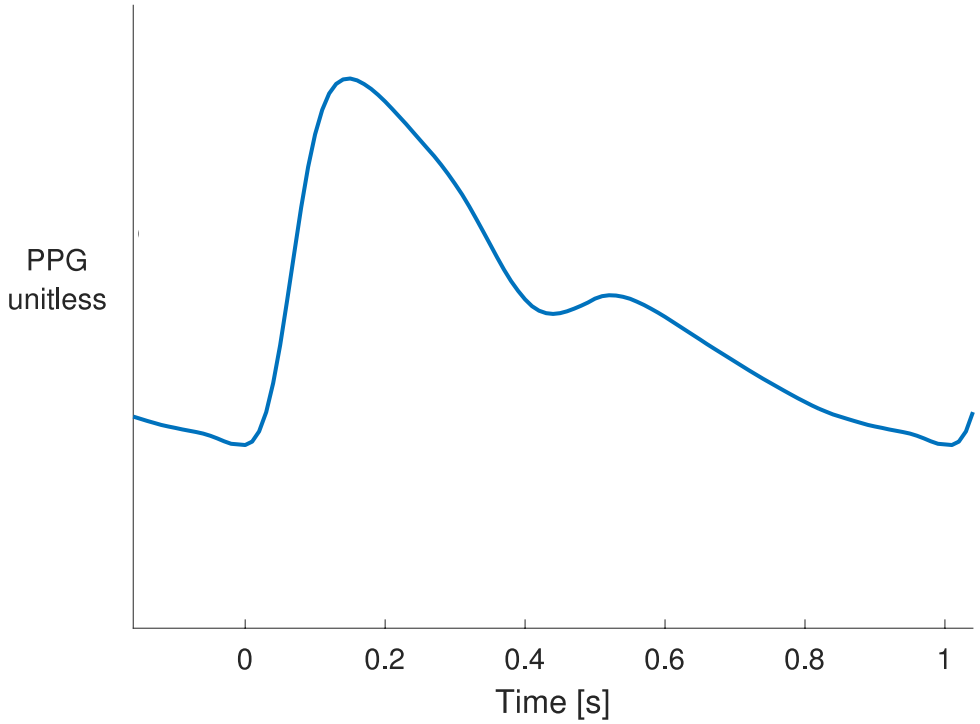
8 hospital admissions

£360k healthcare costs



Sources: [1], [2]

Arterial Pulse Wave

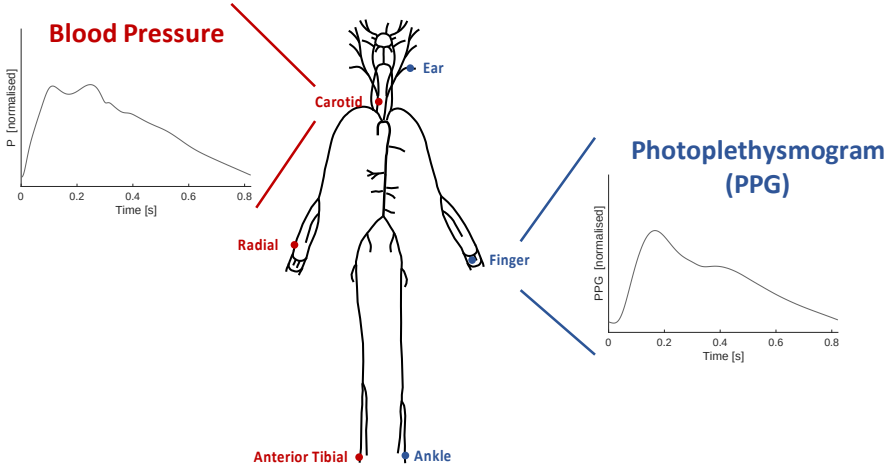


Blood pressure measurement

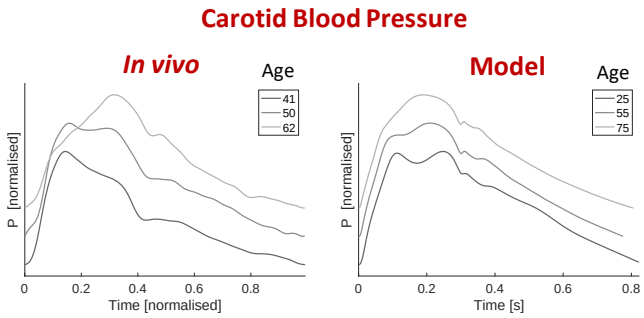
Pulse oximeter (photoplethysmogram)

Smart devices (photoplethysmogram)

Sources: [3], [4], [5], [6], [7]



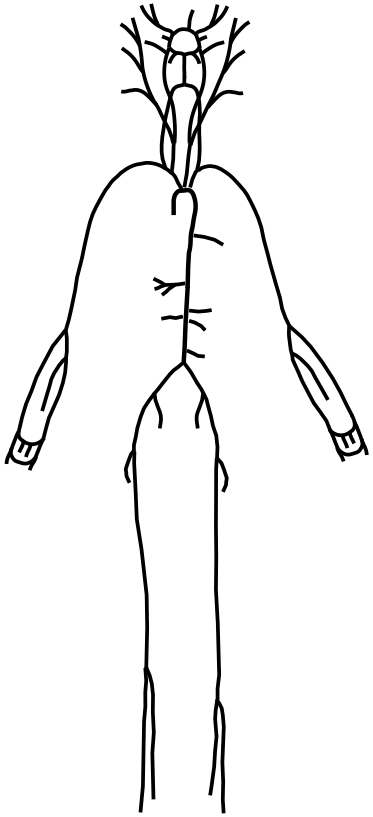
Adapted from: [8]



Source: [9]

Methods

1-D Arterial Blood Flow Modelling



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Arterial network:

- Thin, deformable cylindrical tubes
- Properties described by a single axial coordinate *x:*
  - *Length, luminal diameter, wall properties*

Boundary Conditions:

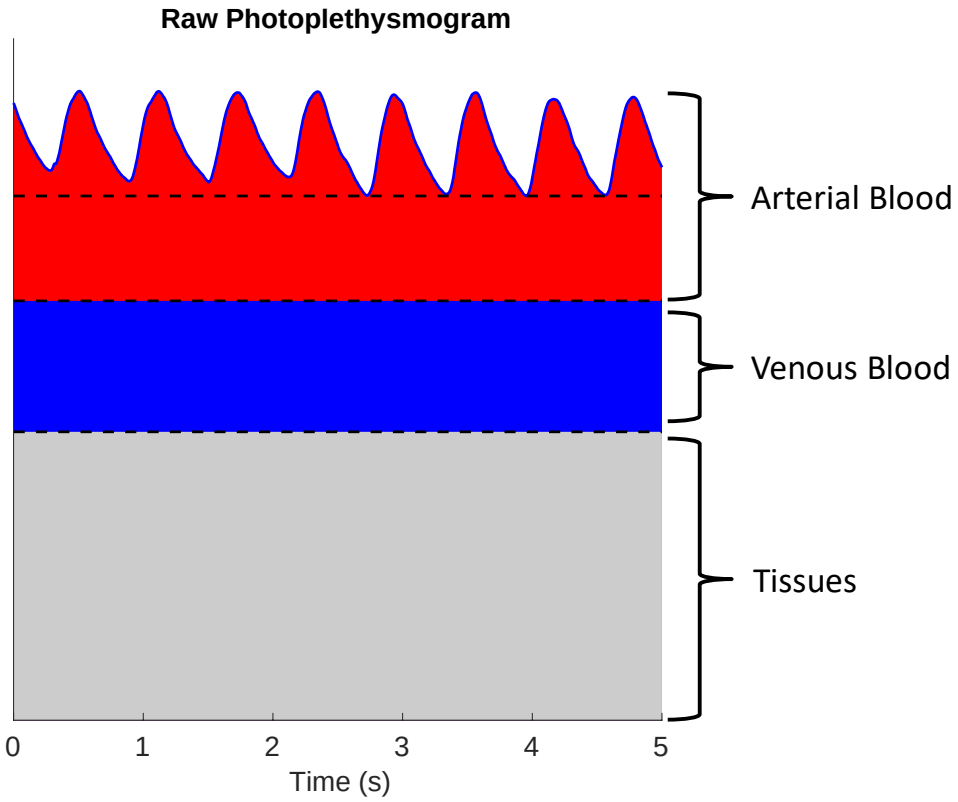
- Periodic inflow waveform
- Terminal Windkessel models

1-D formulation of pulse wave propagation:

- Non-linear 1D equations of incompressible and axisymmetric flow
- Conservation of mass, linear momentum and energy
- Visco-elastic vessels

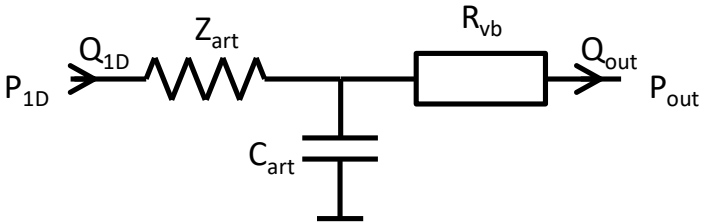
Ref: Alastruey et al, Arterial Pulse Wave Haemodynamics, 2012

Modelling the Photoplethysmogram

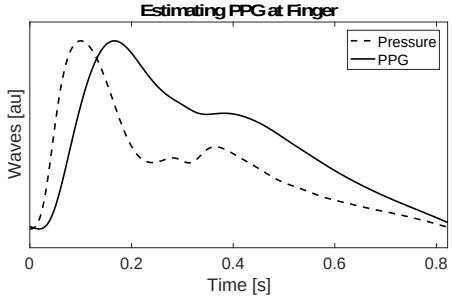


Source: [5]

Modelling



$$PPG(T) = \int_0^T Q_{1D} - Q_{out} dt$$



Source: [9]

Modelling Healthy Ageing

Changed with age	No change with age
↑ Luminal diameter of larger arteries (24)	Luminal diameter of remaining arteries (4)
↑ Length of proximal aorta (4)	Length of remaining arteries (3)
↑ Pulse wave velocity (25)	Left ventricular ejection time (9)
↓ Stroke volume (10)	Time to peak aortic flow (3)
~~ Heart rate (21)	Aortic reverse flow volume (1)
~~ Mean blood pressure	

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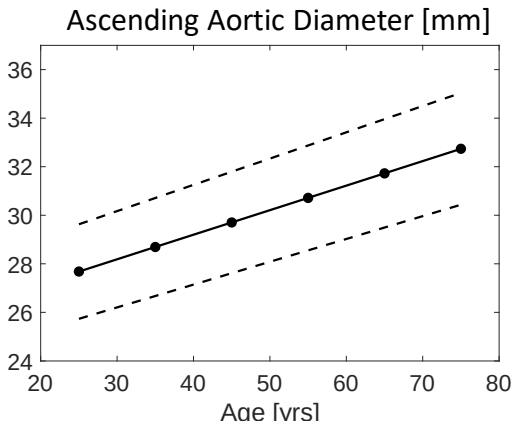

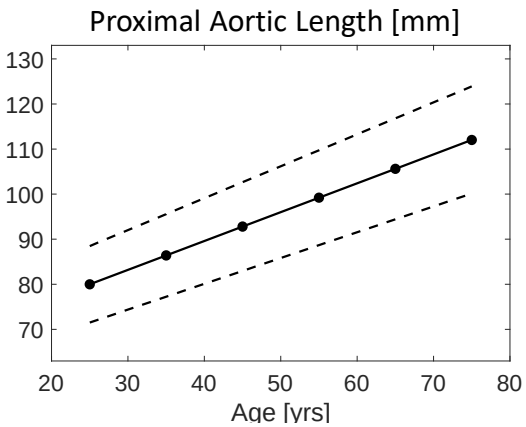

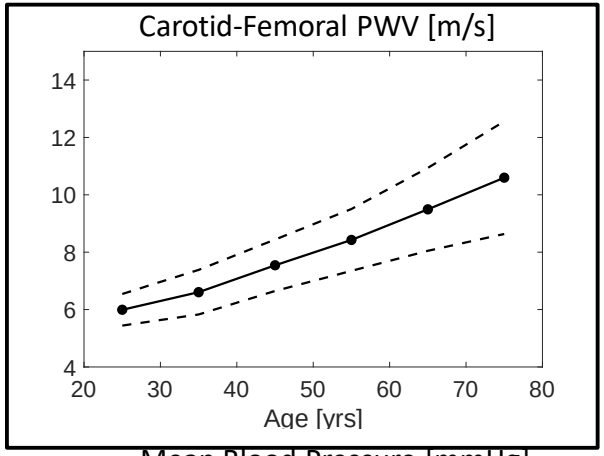

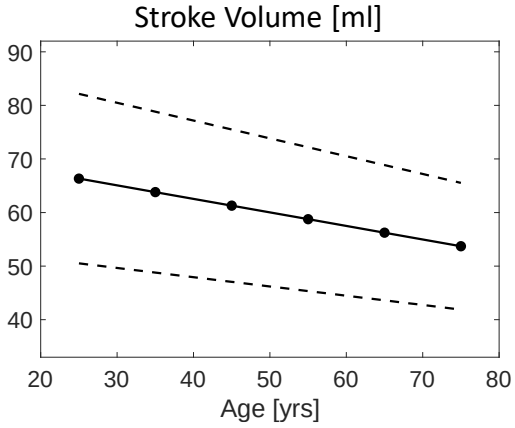

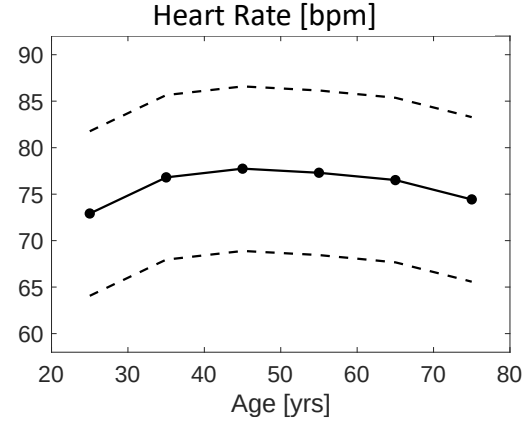

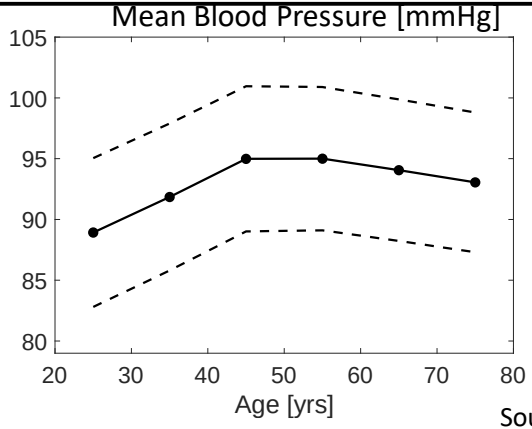

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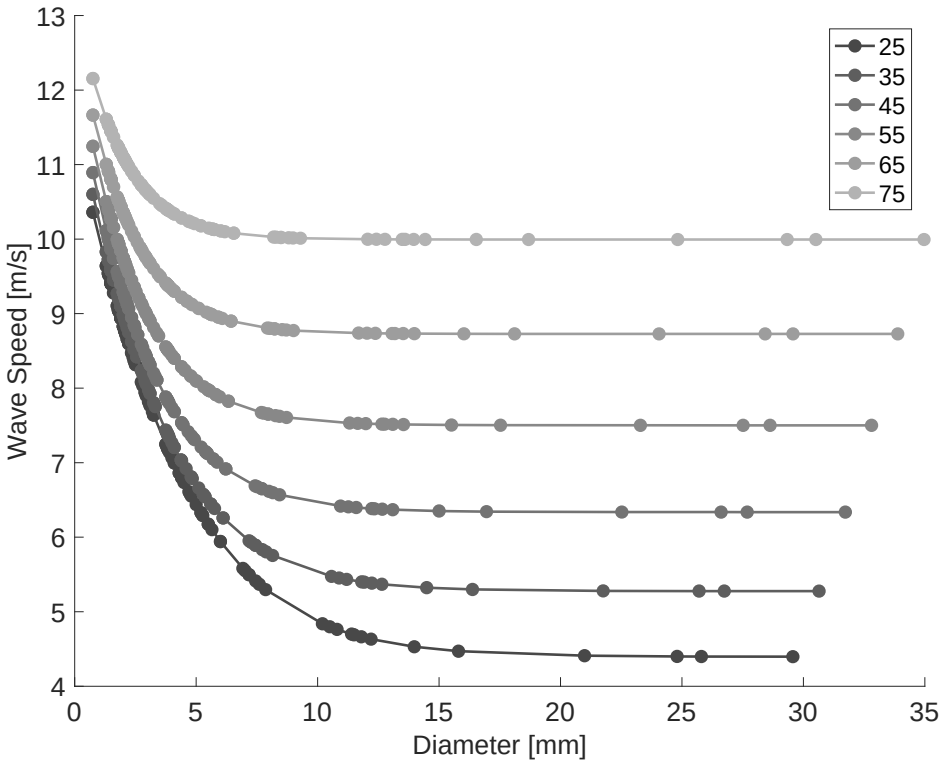

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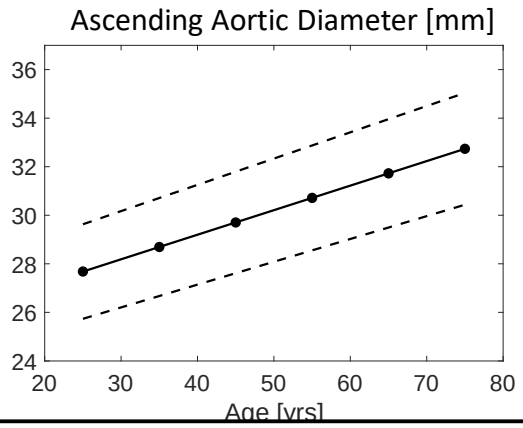

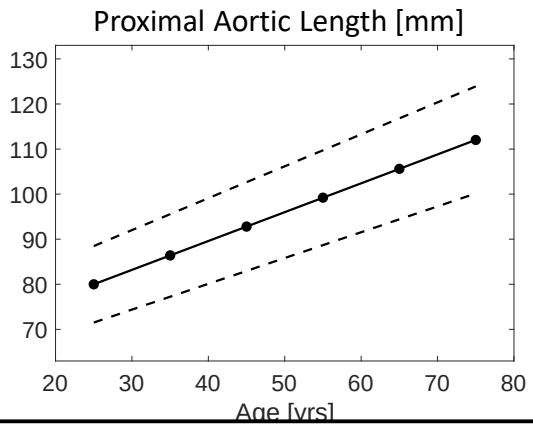

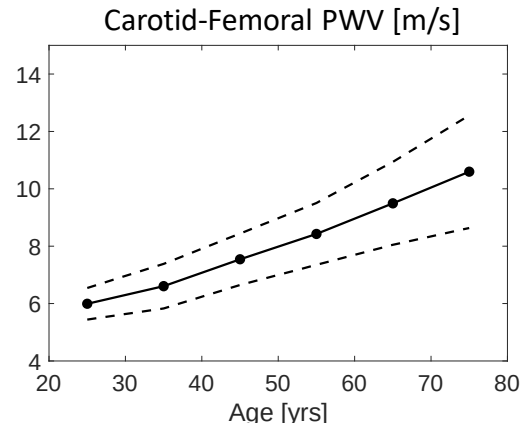

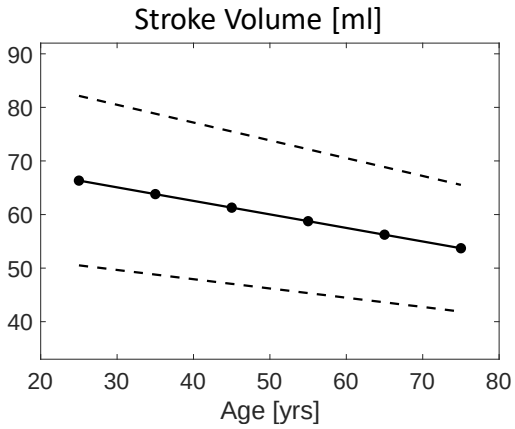

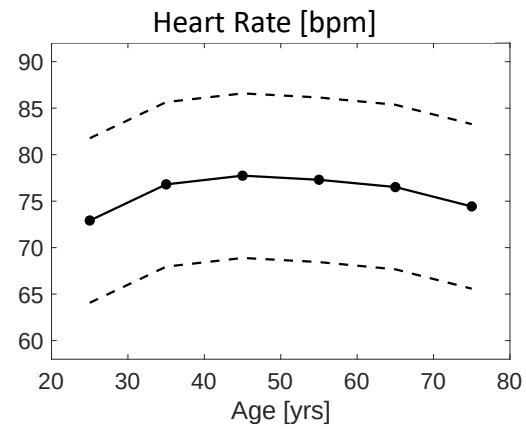

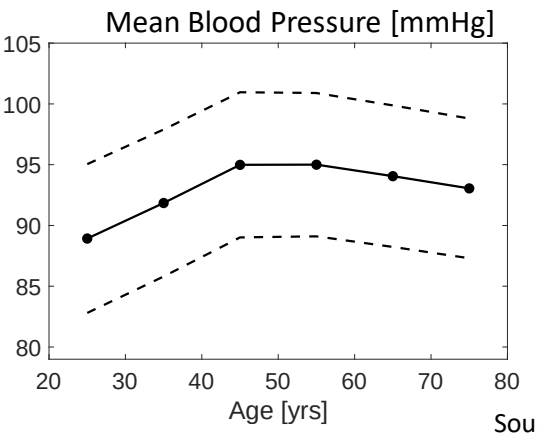

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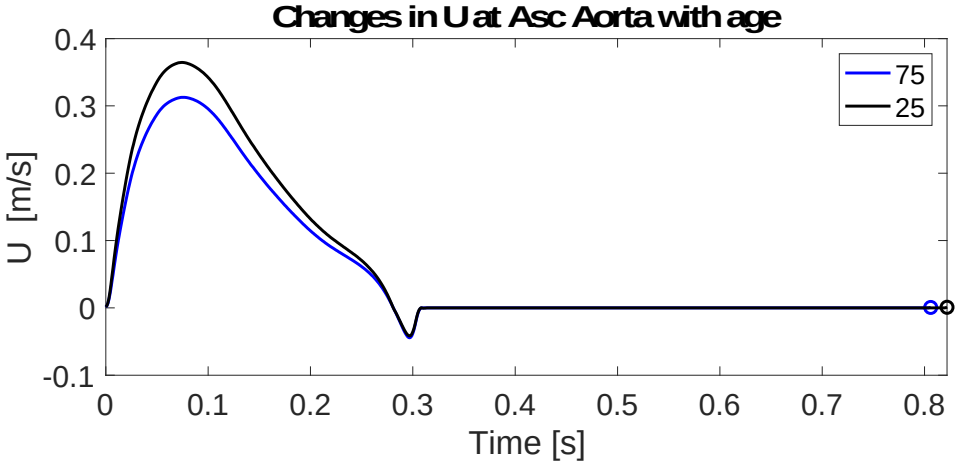
Modelling Changes with age



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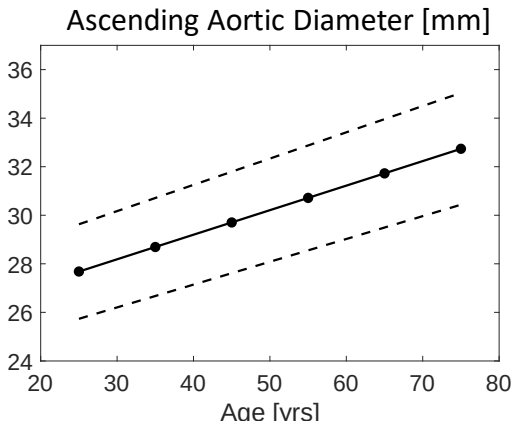

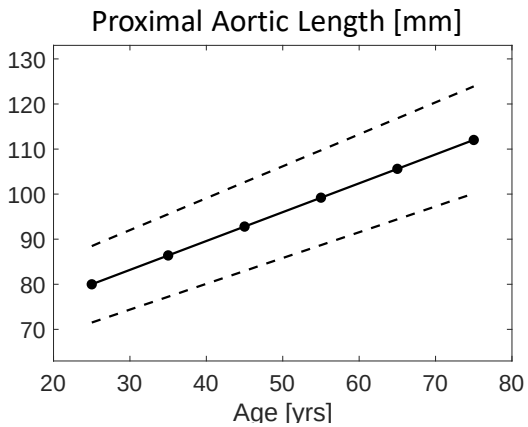

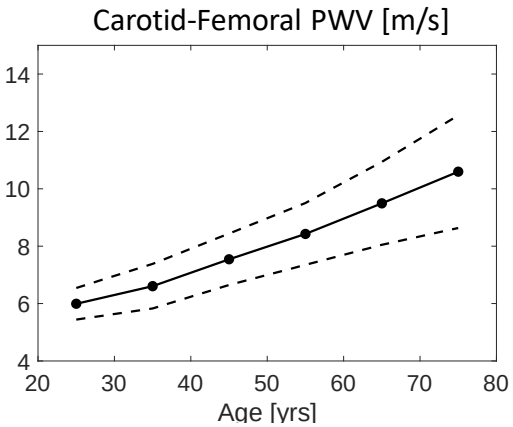

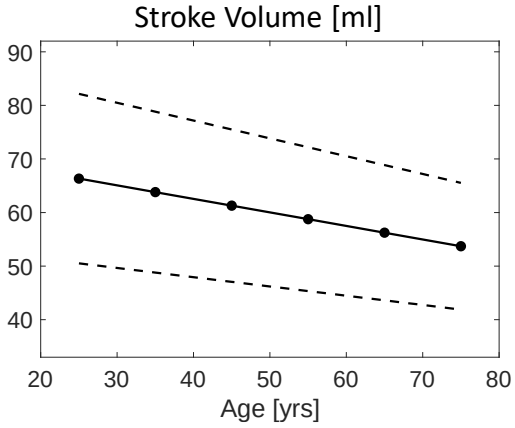

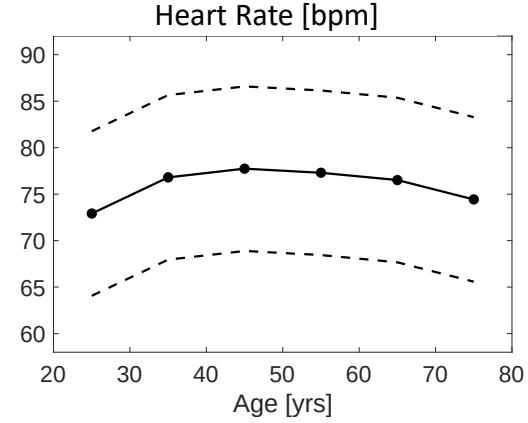

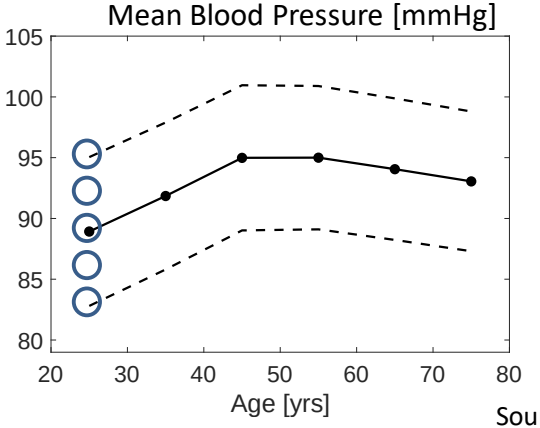

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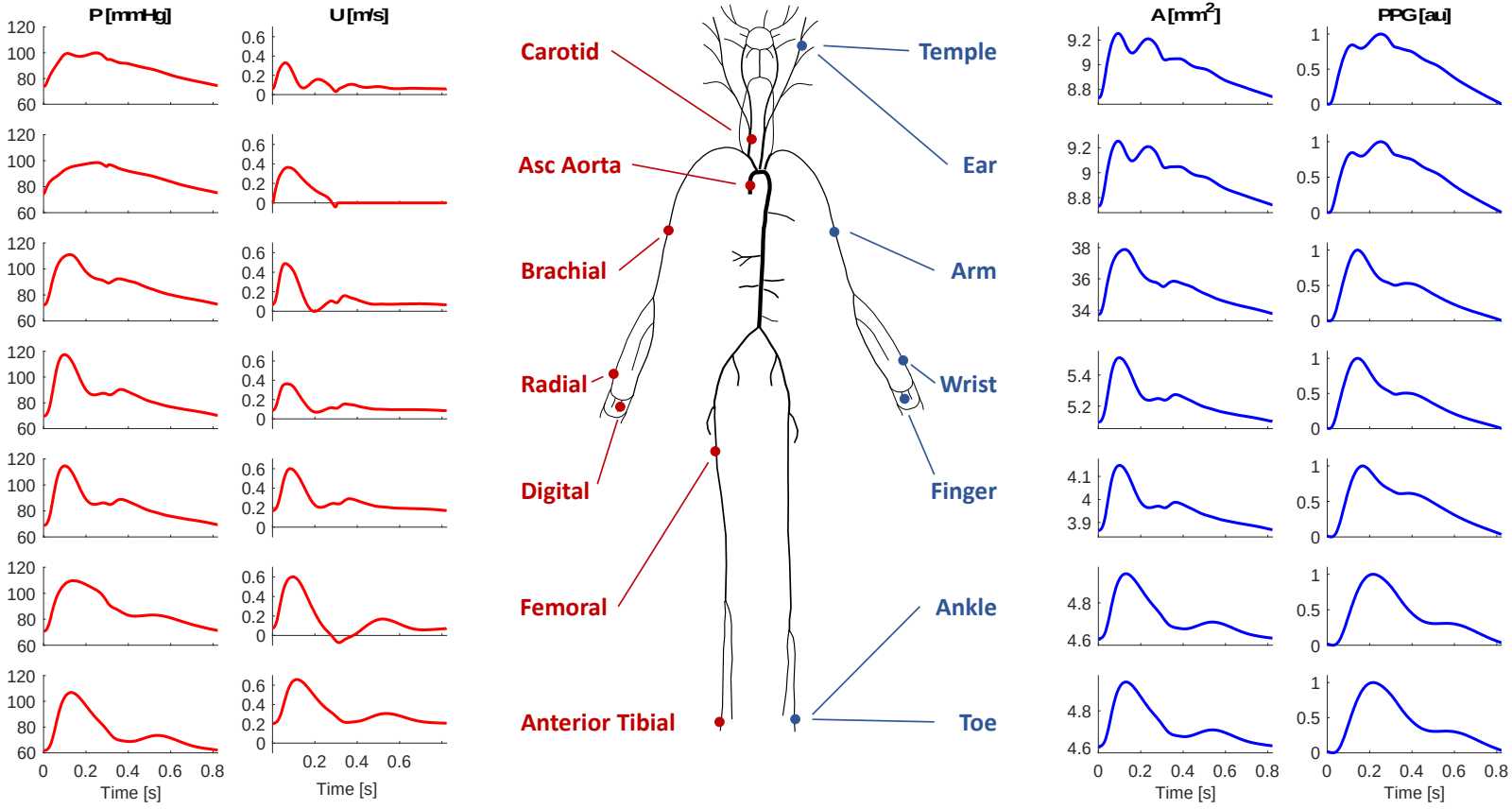
Results

Baseline subject



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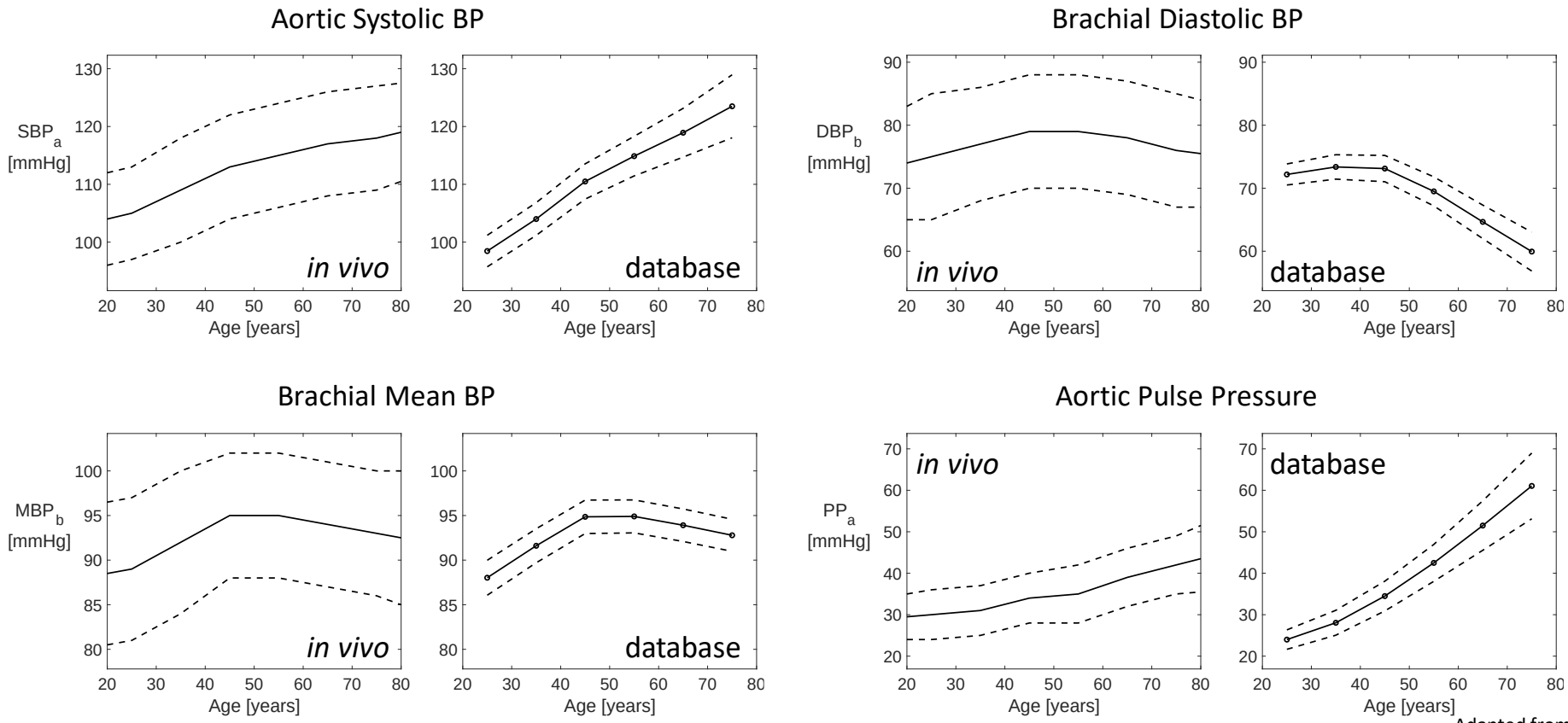
Comparison with *in vivo* data



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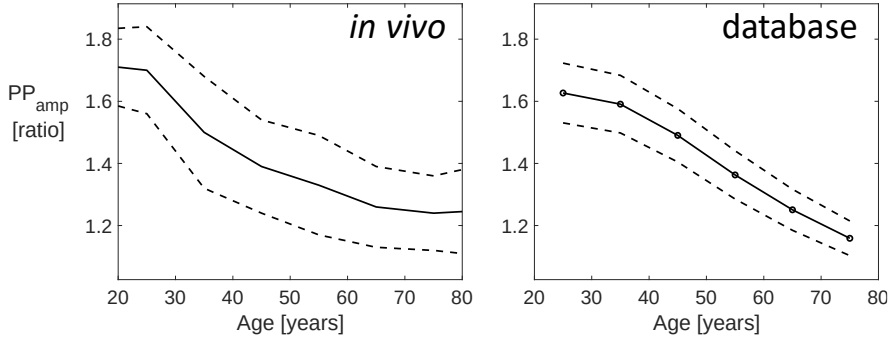
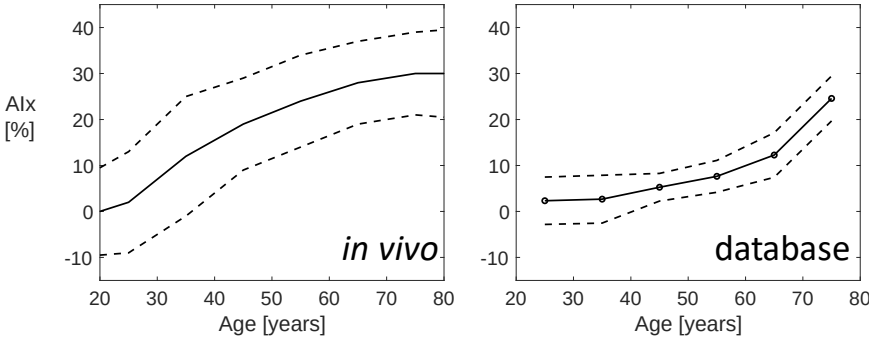
Comparison with *in vivo* data

Pulse Pressure Amplification ratio



Augmentation Index

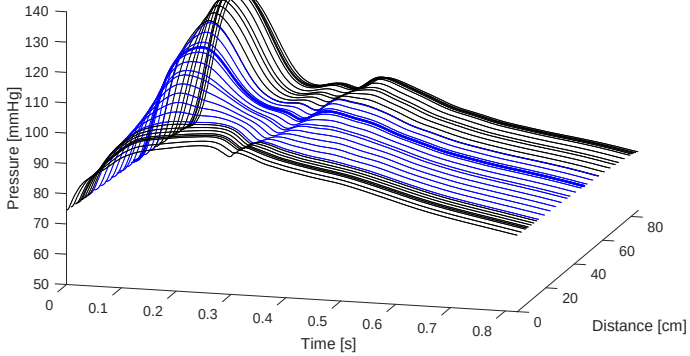


Aortic root

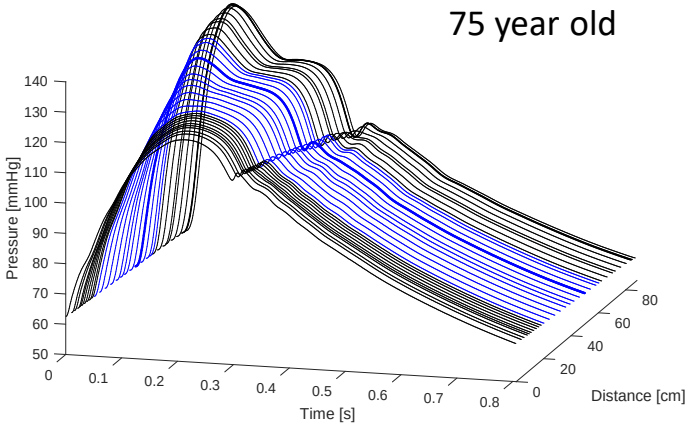
to

Digital artery

25 year old



75 year old



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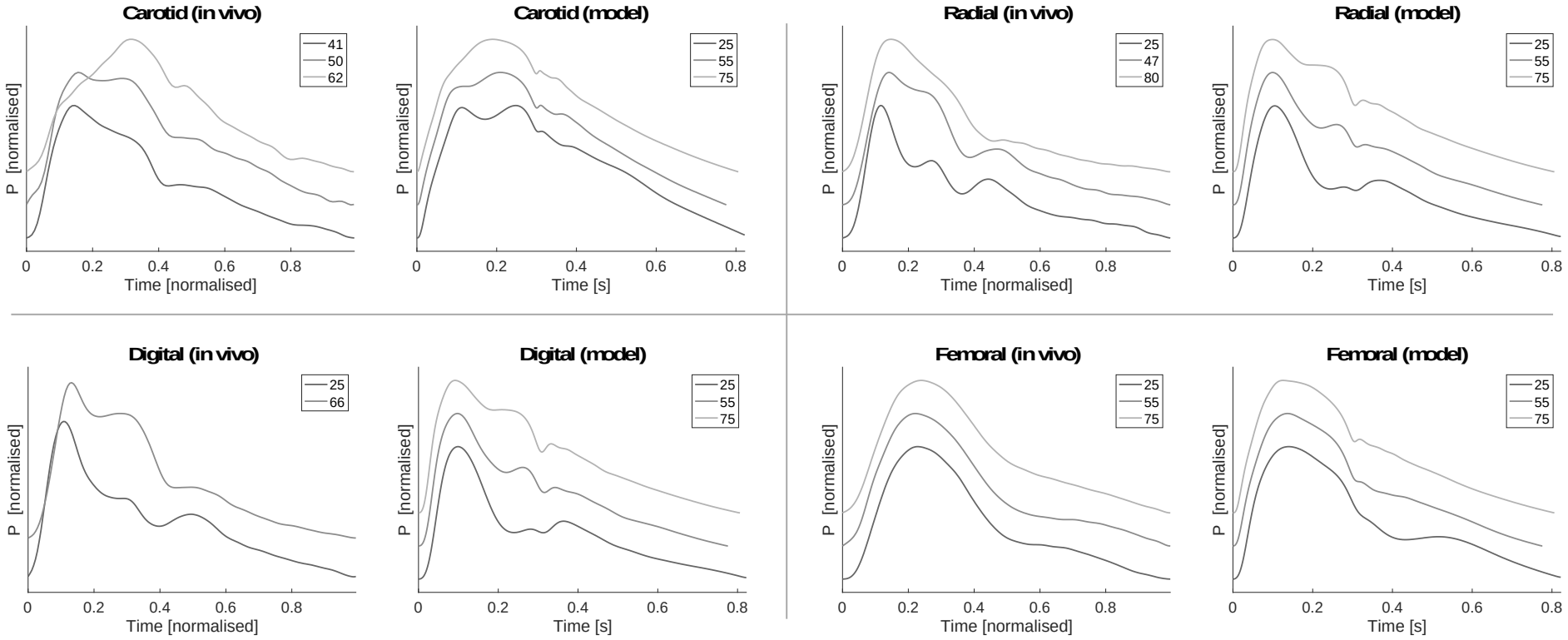

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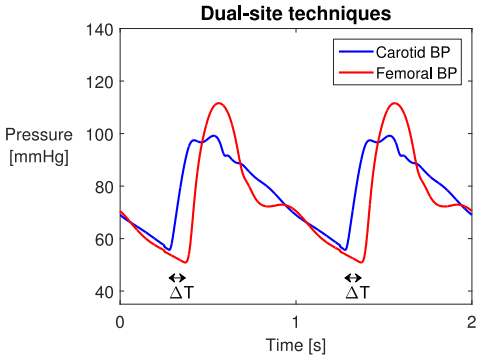
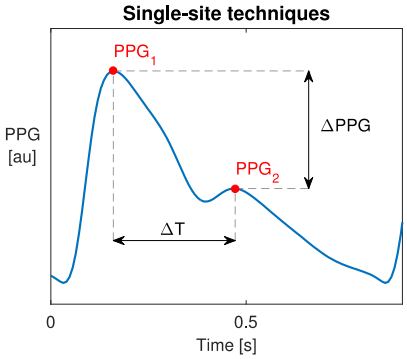
Case Study

Determinants of Arterial Stiffness Indices





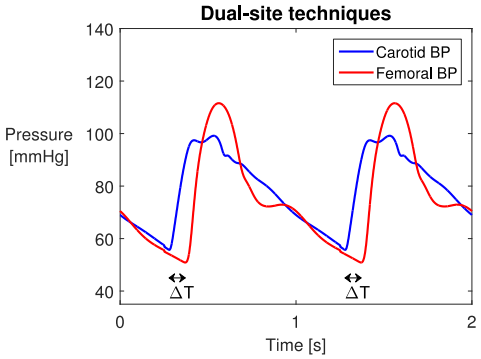
Simultaneous
Blood Pressures

Single
Photoplethysmogram

Determinants of Arterial Stiffness Indices

Correlation with aortic pulse wave velocity (PWV):

	PWVs (n = 5)	ASIs (n = 192)
R^2 : Coefficient of determination	0.94 – 1.00	**0.00 – 0.80**



Simultaneous
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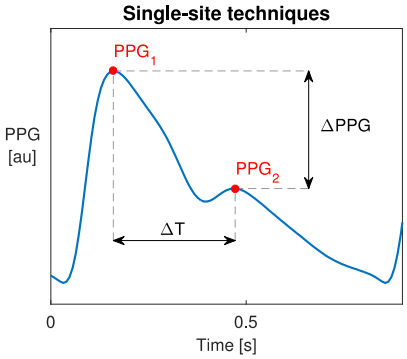
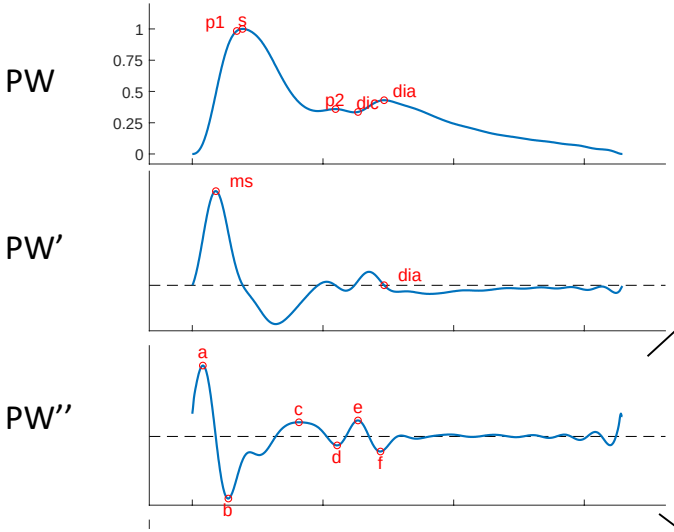
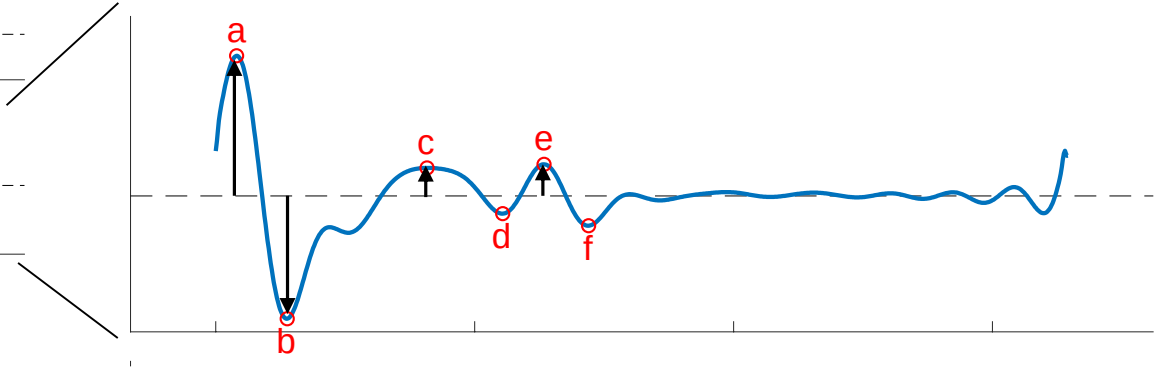


Single
Photoplethysmogram

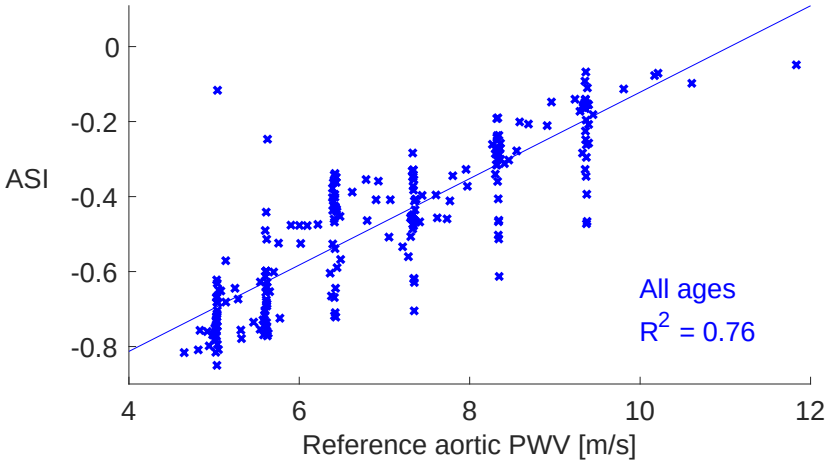
Determinants of Arterial Stiffness Indices



$$\text{Modified Ageing Index} = \frac{PW'(b) - PW'(c) - PW'(d)}{PW'(a)}$$



Determinants of Arterial Stiffness Indices



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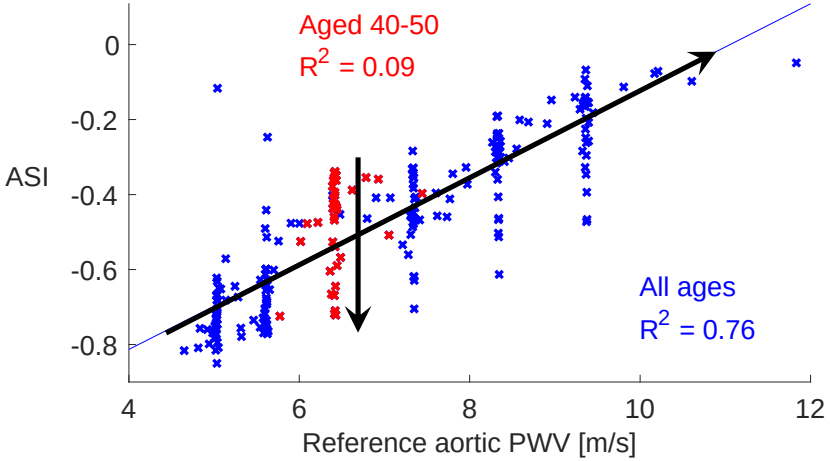
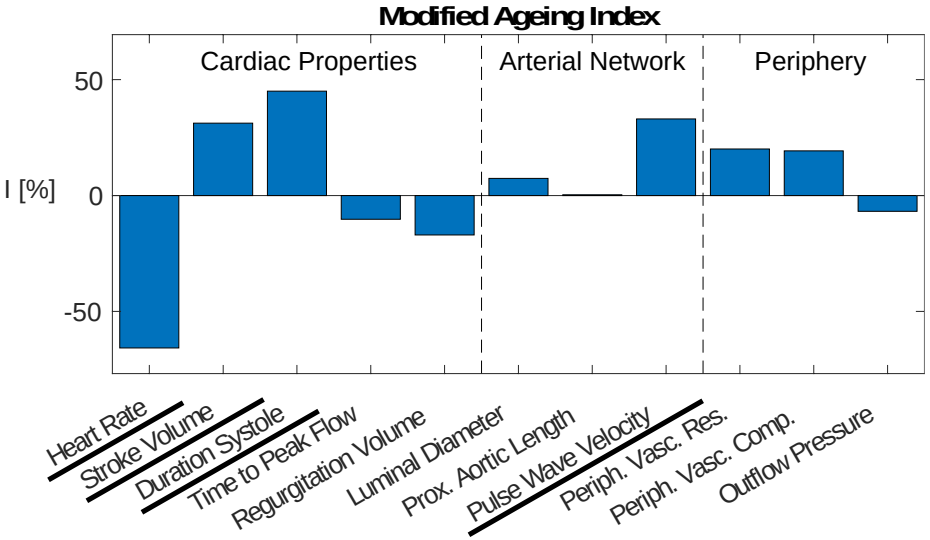
Determinants of Arterial Stiffness Indices





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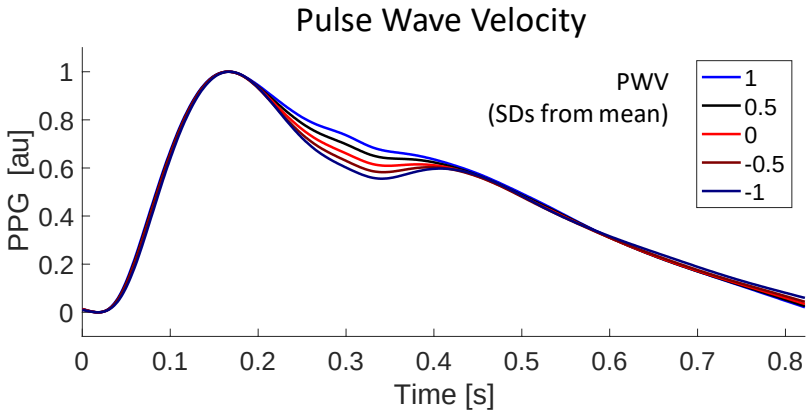
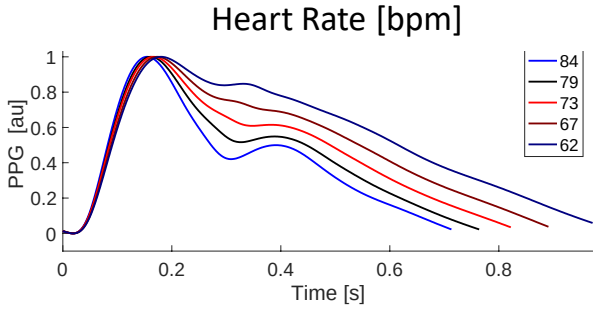
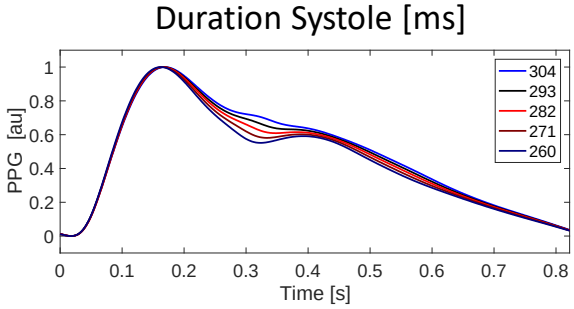
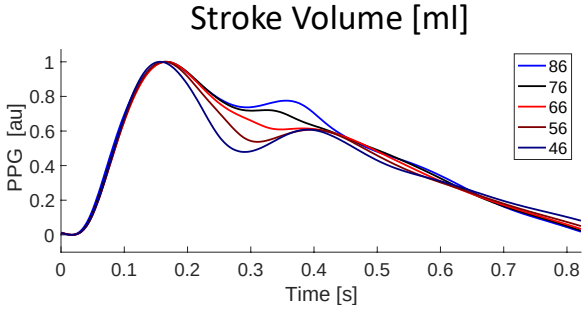




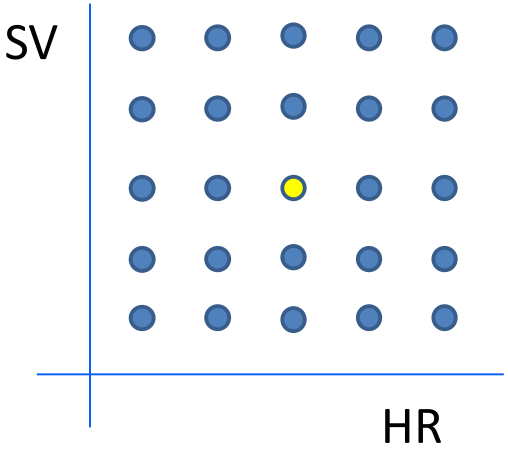




Adapted from: [10]

Further Work

Constructing a Virtual Population



http://haemod.uk/

Source: [9]

Conclusions

Conclusions

Developed methods for:

- Modelling affects of ageing
- Modelling the photoplethysmogram

Application:

- *in silico* development of pulse wave algorithms

References & Acknowledgment

Virtual Population Methodology:

Willemet M. *et al.,* " A database of virtual healthy subjects to assess the accuracy of foot-to-foot pulse wave velocities for estimation of aortic stiffness". *Am J Physiol Heart Circ Physiol*, *309*(4):H663-7, 2015.

Modelling Approach:

Charlton P. H. *et al*. "Assessing mental stress from the photoplethysmogram: a numerical study. *Physiological Measurement*, *39*(5):054001, 2018.

Ongoing Work: http://haemod.uk/

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