A numerical assessment of methods to estimate aortic stiffness from arterial pulse waves

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Summary

Motivation: It is not clear whether arterial stiffness indices (ASIs) derived from a single pulse wave are precise enough for clinical use.

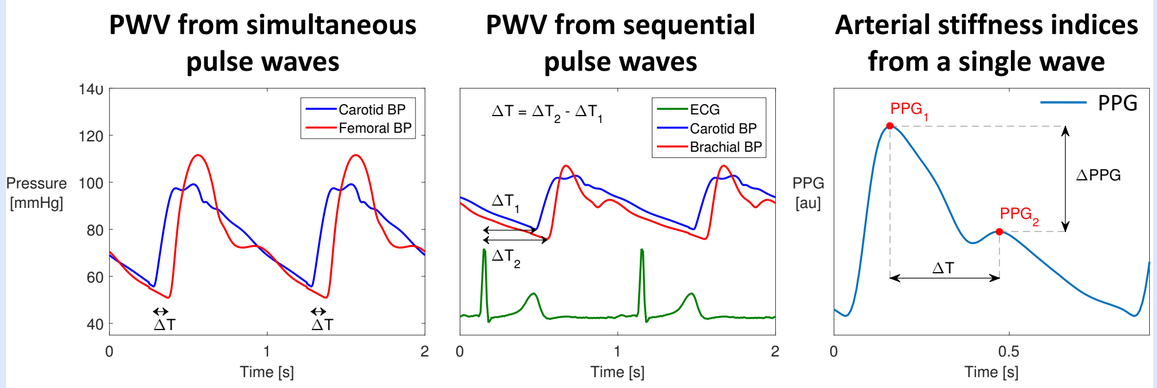
Aim: To assess the performance of ASIs, and compare them with traditional pulse wave velocity (PWV) measurements.

Methods: Pulse waves were simulated for subjects of different ages with a range of cardiovascular properties. The performance of ASIs and PWVs was assessed through comparison with reference aortic PWV.

Results: ASIs performed reasonably, although not as well as PWVs. ASI performance was poor when considering only subjects of a certain age.

Conclusion: ASIs cannot replace PWVs, but may have utility in some settings. The influence of other cardiovascular properties on ASIs should be reduced.

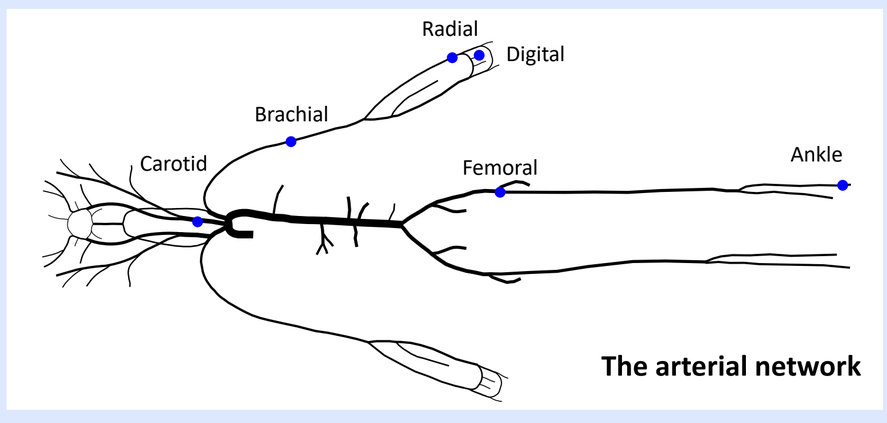
Estimating aortic stiffness



We assessed methods for estimating aortic stiffness from each category.

Methods

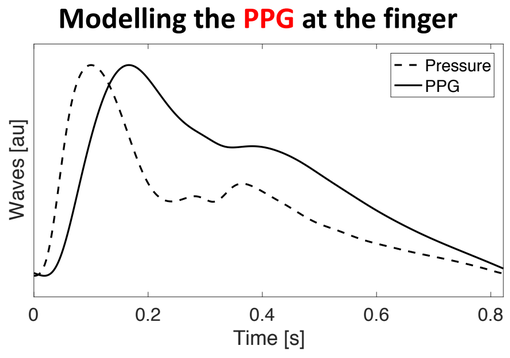
We used a 1-D model of pulse wave propagation to simulate arterial pulse waves at several anatomical sites:



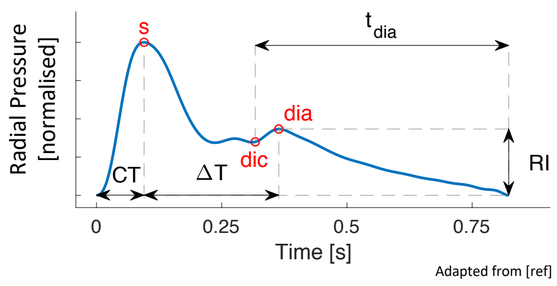
Adapted from [ref]

Photoplethysmogram (PPG) waves were simulated as the vascular bed blood volume. Fiducial points were identified on each pulse wave, and 32 **arterial stiffness indices (ASIs)** were extracted (below right), from pressure and PPG waves at carotid, radial and digital arteries (see [ref] for details of ASIs).

Modelling the PPG at the finger



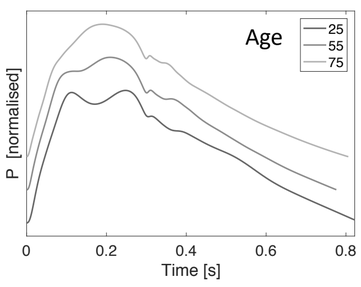
Identifying fiducial points and extracting arterial stiffness indices (ASIs)



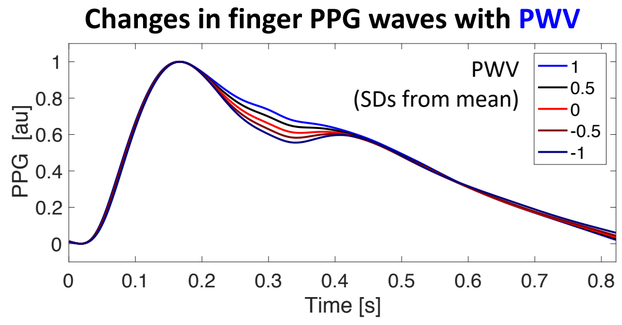
Adapted from [ref]

Arterial pulse waves were simulated for 258 virtual subjects **aged** from 25 to 75. Individual **cardiovascular properties** were varied across normal ranges.

Changes in carotid pressure waves with age



Changes in finger PPG waves with PWV



Results

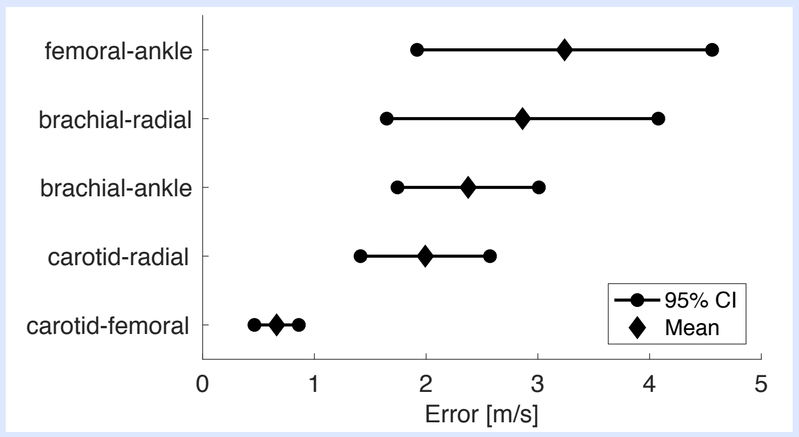
Correlation with reference aortic PWV

PWV measurements provided better performance than ASIs derived from a single pulse wave, as shown by higher correlations with aortic PWVs.

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

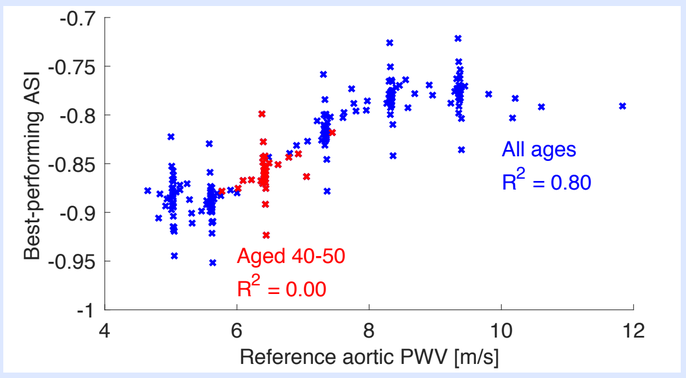
Performance of PWV measurements

Carotid-femoral PWV had greatest accuracy (smallest mean error) and precision (smallest 95% confidence interval of errors). All PWVs over-estimated aortic PWV (indicated by positive errors).



Performance of single-site ASIs

The top-performing ASIs included ASIs calculated from pressure and PPG waves, and at carotid, radial and digital sites, demonstrating the possibility of using a wide range of pulse waves to assess aortic stiffness.



However, performance reduced dramatically when considering only a certain age range (*e.g.* 40-50 years). This was because other cardiovascular properties besides aortic PWV had a substantial effect on ASIs.

Conclusion

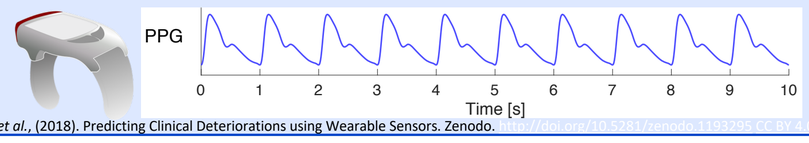
ASIs exhibited reasonable performance. However, further work is required to reduce the effects of other cardiovascular properties on ASIs.

Next Steps

1. Extend the dataset to represent a population exhibiting healthy ageing and normal physiological variations.

2. Combine single-site ASIs to develop a novel ASI with improved performance.

3. Smart wearables measure the PPG, providing opportunity for continuous cardiovascular assessment.



[ref] Charlton, P. H. *et al.,* Assessing mental stress from the photoplethysmogram: a numerical study. *Physiological Measurement*, *39*(5), 054001, 2018. DOI: 10.1088/1361-6579/aabe6a . CC BY 3.0

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