

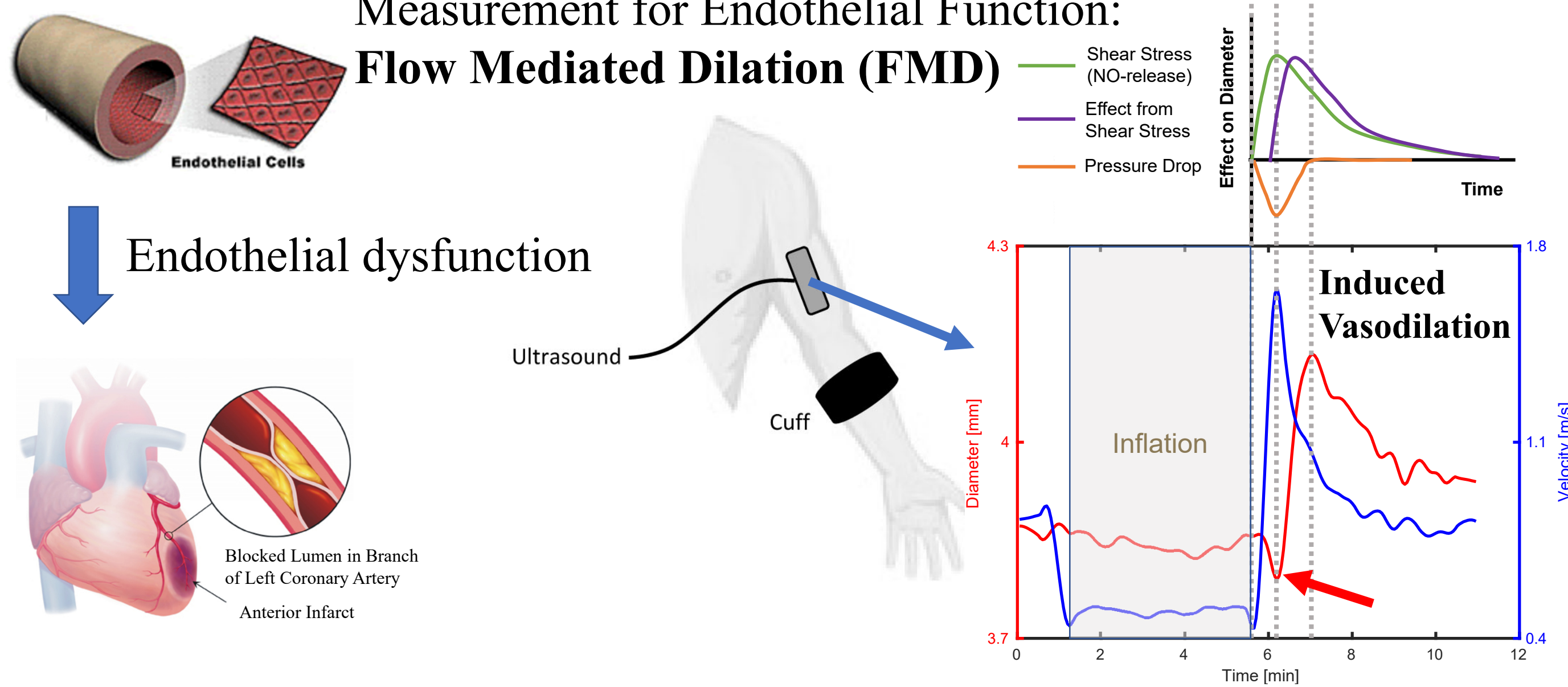
Understanding the role of blood pressure, wall shear stress and arterial wall stiffness in flow mediated dilation: A computational and *in-vivo* study

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1. Motivation & Objective

Measurement for Endothelial Function:
Flow Mediated Dilation (FMD)



- **Current FMD:** assumes vasodilation entirely induced by the increase in wall shear stress (WSS).
- **Issue:** there is evidence of vasodilation being affected by other confounding factors, such as arterial wall stiffness and blood pressure¹.
- **Aim** to investigate the effects of arterial wall stiffness on the results of FMD using computational blood flow modelling.

2. Study Design

Hemodynamic Solver for blood flow (Q), blood pressure (P), and cross-section area (A):

$$\begin{cases} \frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = 0 & \text{Conservation of mass} \\ \frac{\partial Q}{\partial t} + \frac{\partial}{\partial x} \left(\alpha \frac{Q^2}{A} \right) + \frac{A}{\rho} \frac{\partial P}{\partial x} = \frac{f}{\rho} & \text{Conservation of momentum} \end{cases}$$

Tube Law:

$$P = P_0 + \frac{\beta(x)}{A_0(x)} (\sqrt{A} - \sqrt{A_0(x)}) + \frac{\Gamma(x)}{A_0(x)\sqrt{A}} \frac{\partial A}{\partial t}$$

$$\beta(x) = \frac{3}{4} \sqrt{\pi} E(x) h(x)$$

i) Prescribe the change of peripheral resistance and ii) change Young's modulus (E) induced by the increase in WSS (τ).

ii) The relationship between WSS (τ) & Young's modulus (E)² (Endothelial function):

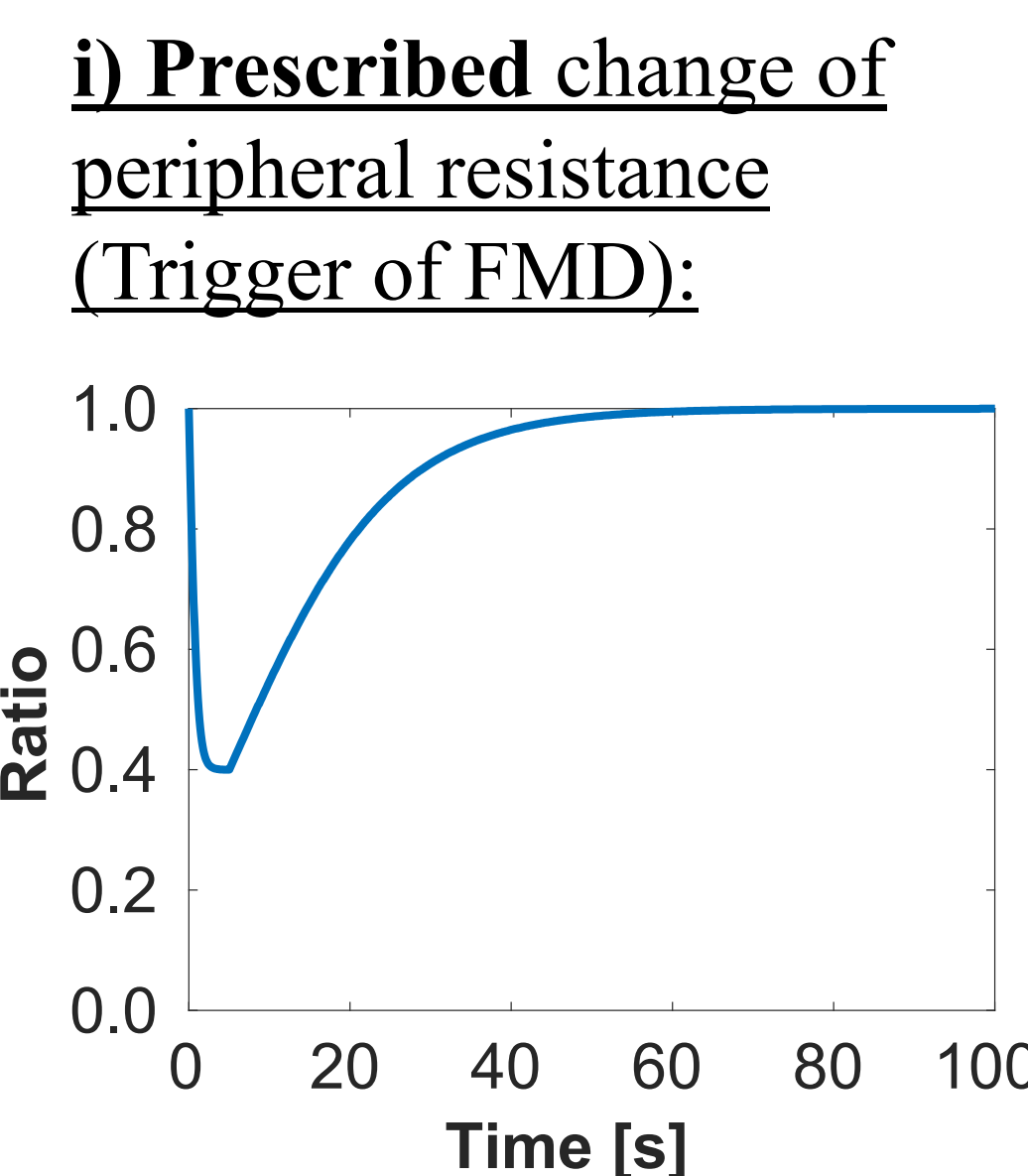
$$E(t) = E_{base}(1 + \delta E)$$

$$\frac{d\delta E(t)}{dt} = \frac{1}{C_d} (\alpha_\tau \tau_{cum}(t) - \delta E(t))$$

$$\frac{d\tau_{cum}(t)}{dt} = \delta\tau - \frac{\ln(2) \tau_{cum}}{HL}$$

$$\delta\tau(t) = \tau_{base} - \tau(t)$$

$$\tau(t) = \mu \frac{U}{R} (\xi + 2) \quad \xi = \frac{2 - \alpha}{\alpha - 1}$$



4. Discussion & Conclusion

- We have developed a novel numerical model to simulate the process of FMD.
- In-silico FMD results agree well with in-vivo data: the simulation can capture the surge increase in velocity right after cuff deflation, the diameter drop right after cuff deflation is followed by a diameter increase.
- For the same prescribed endothelial function (relating WSS to Young's modulus variation) and decreased peripheral resistance, FMD increases with decreasing arterial stiffness.

5. Future Plan

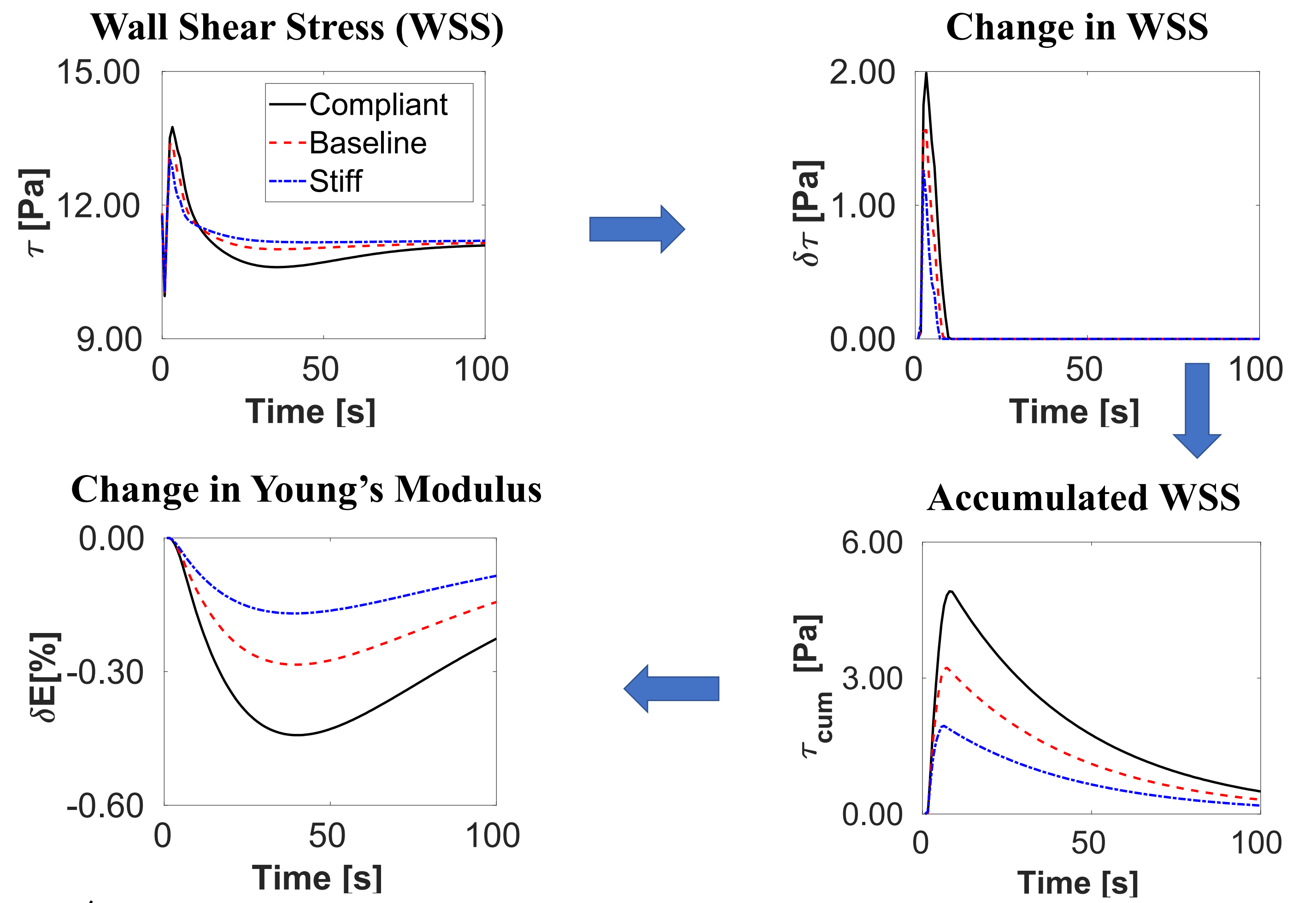
- Investigate other confounding factors that may affect the results of FMD using our novel numerical model developed in this study.
- Apply the numerical model to investigate endothelial-dysfunction related diseases (e.g. coronary artery disease).
- Obtain a new FMD index that is not affected by confounding factors.

References

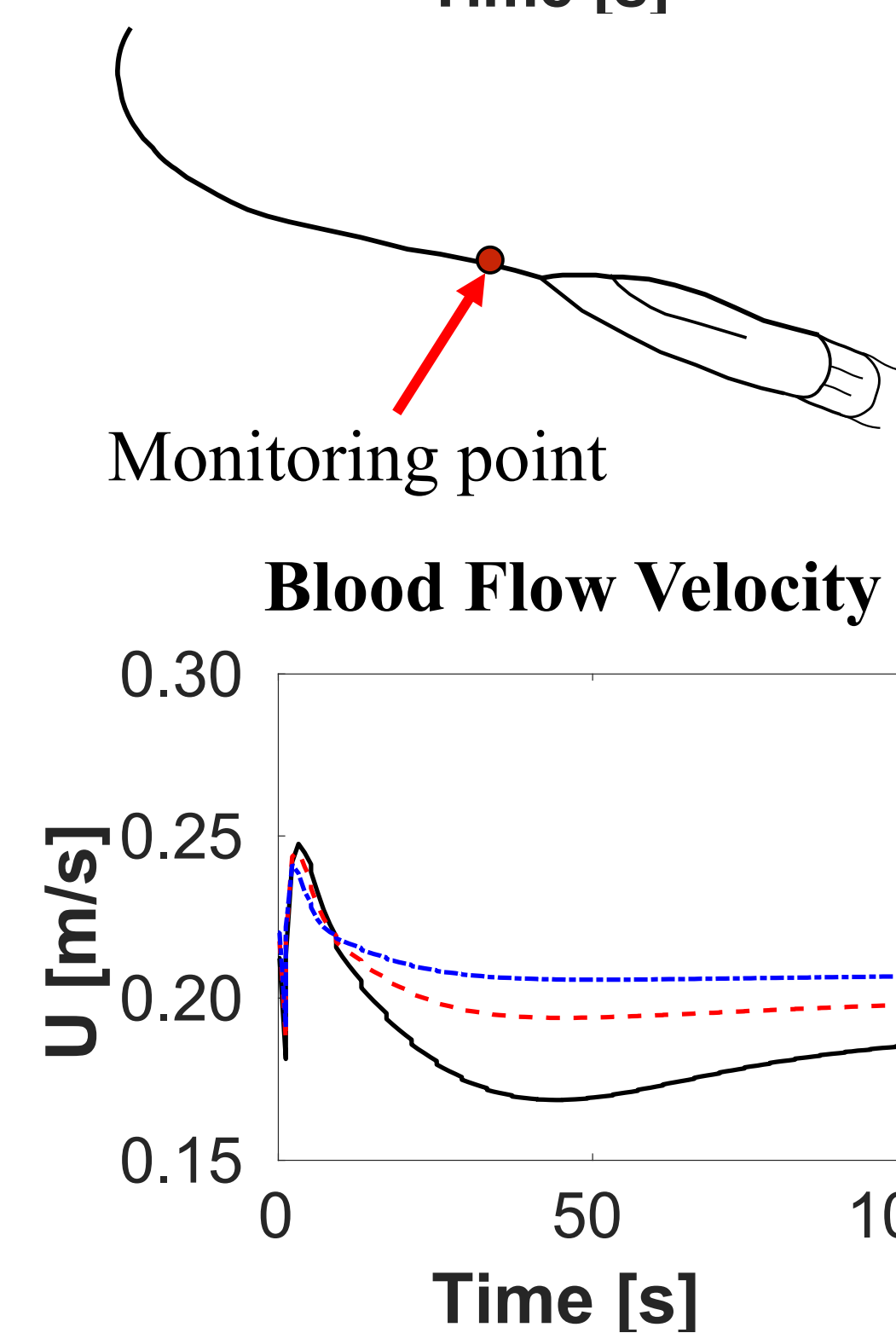
1. Jiang, Benyu, *et al.*, *Hypertension* 57 (6) (2011): 1145-1150.
2. Van Brackle, *et al.*, *Journal of Applied Physiology* 122 (5) (2016): 1292-1303.

3. Results

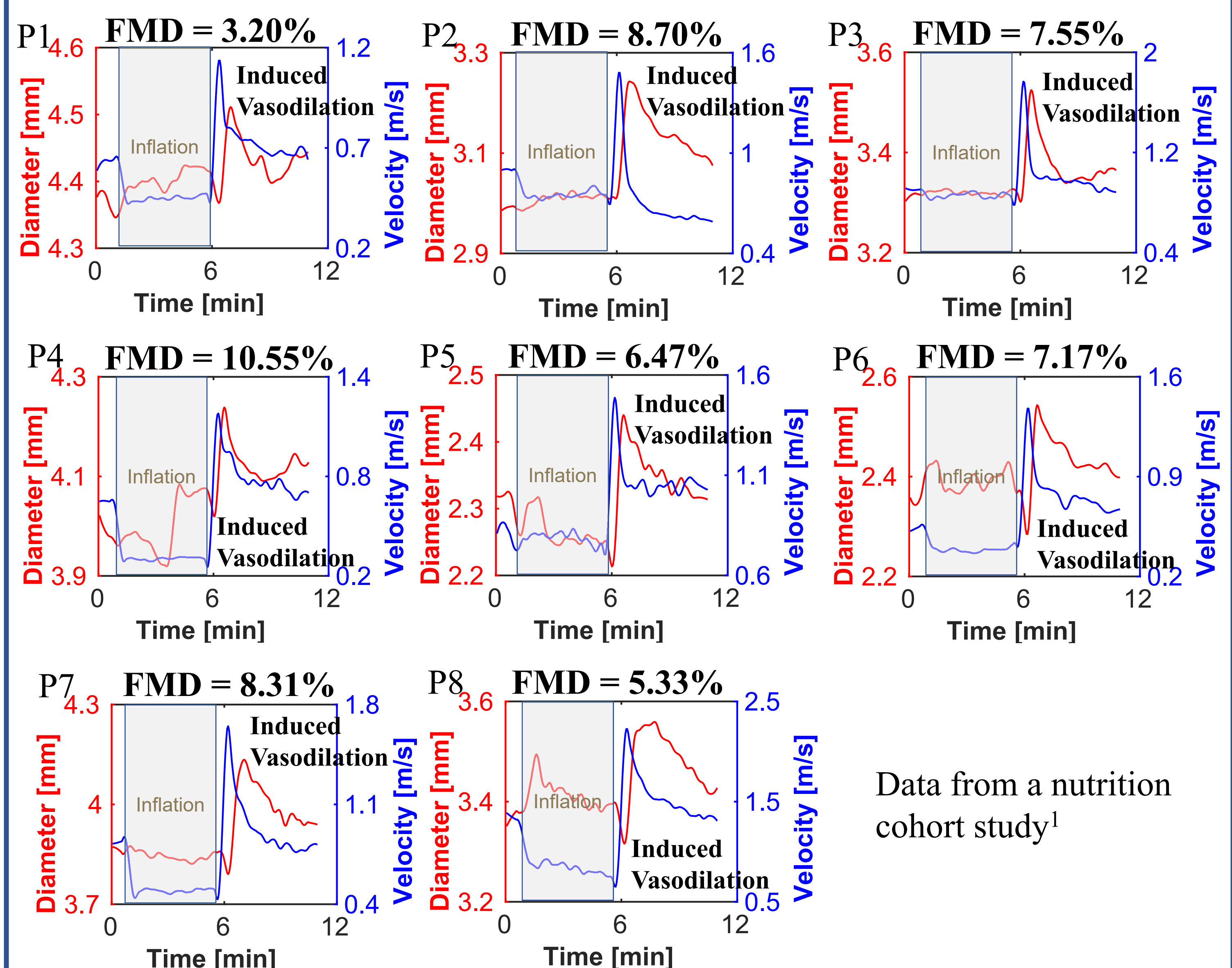
Simulated evolution of key physical variables in FMD (displayed as mean over each cardiac cycle in the brachial artery). Results shown at **baseline** and with **stiffer** or more **compliant** arteries:



	Compliant	Baseline	Stiff
FMD [%]	8.56	5.31	3.17



In-vivo data to test the simulated velocity (U) and diameter (D):



Data from a nutrition cohort study¹

Acknowledgements

This study is funded by a King's College London PGR International Scholarship. Travelling expenses are partly supported by King's College London Centre for Doctoral Studies Travel Award Scheme and a Sargeant Travel Fund award from King's College London.