HOW DIFFERENT LOWER LIMB MOVEMENTS IMPACT ON THE HEMODYNAMICS OF THE FEMOROPOPLITEAL ARTERY: A COMPUTATIONAL STUDY

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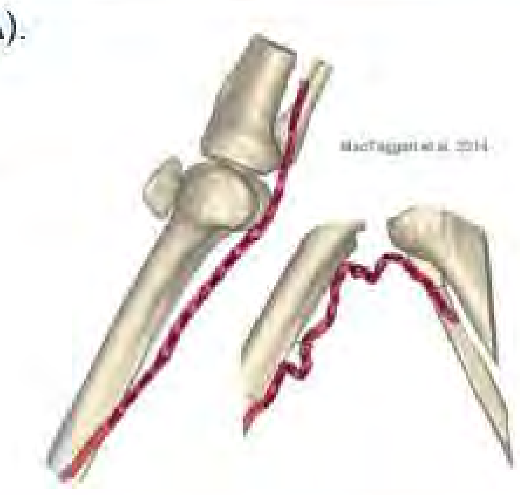
INTRODUCTION

Femoropopliteal artery (**FPA**) is the longest artery of the lower limb, composed proximally by the superficial femoral artery (**SFA**) and distally by the popliteal artery (**PA**).

FPA, characterized by a unique extension and curvature, is one of the most common site for the development of **Peripheral Arterial Disease** (PAD).
The tools to locally analyze hemodynamics in FPA are mainly computer-based, like **computational fluid dynamics** (CFD), which allow the assessment of the local distribution of hemodynamics descriptors [1-3].



MOTIVATION OF THE STUDY

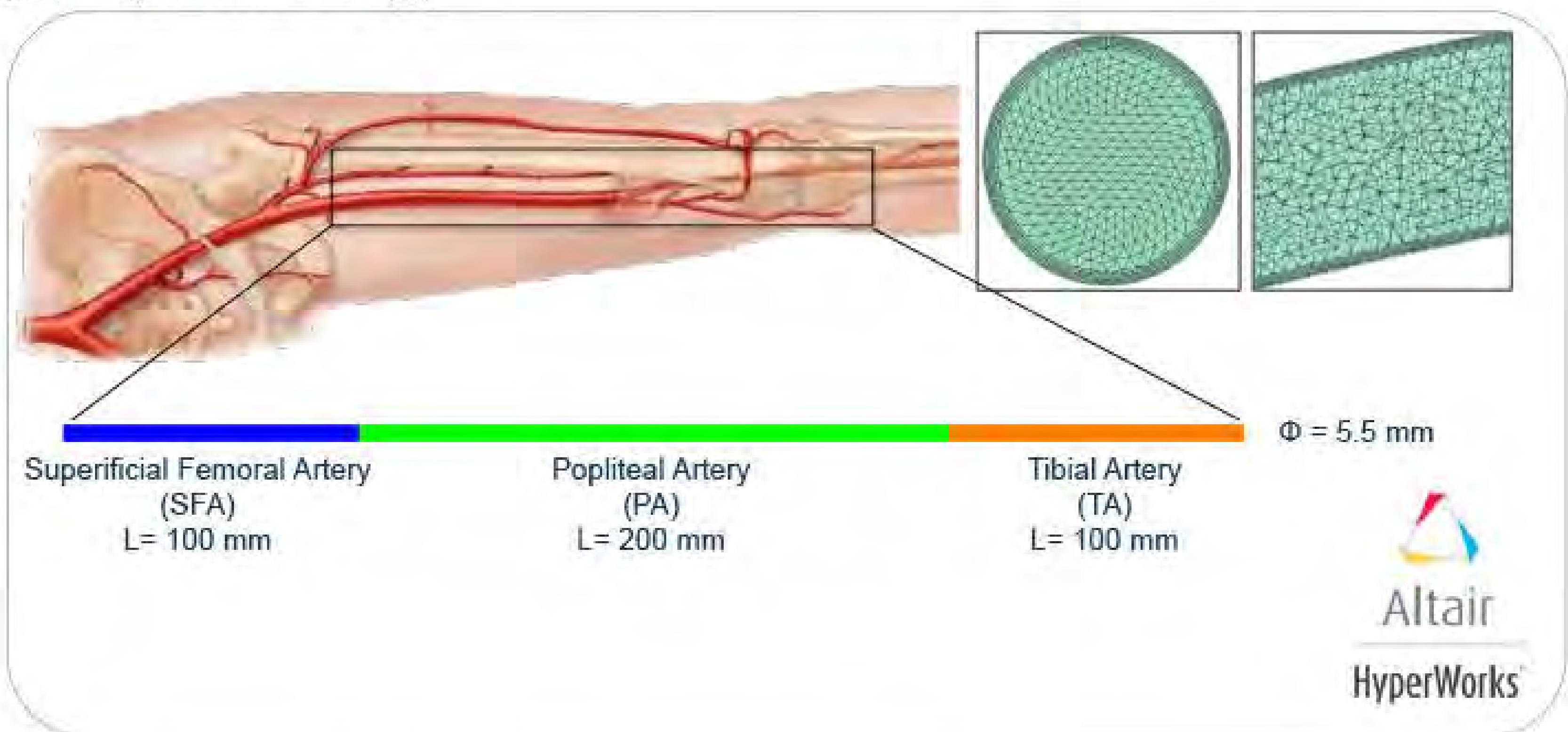
Despite the large amplitude of movements which the FPA is subjected to, no studies are present in the literature on hemodynamics in moving lower limb.

HYPOTHESIS

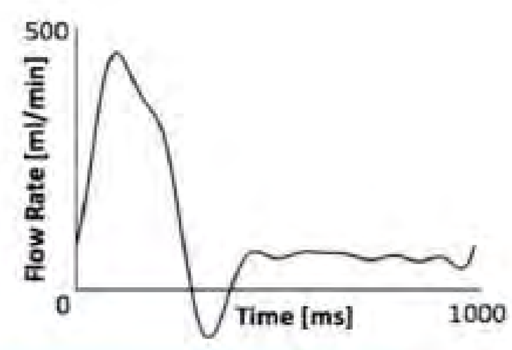
The movement of the lower limb, analyzed through CFD, greatly impacts the FPA hemodynamics.

METHODS

An **idealized geometry** of FPA with human-based dimensions was created using **Hypermesh 2017 (Altair, Troy, Michigan, USA)** and discretized with ~ 250,000 tetrahedral elements with prism layers at the wall [4].



- **Blood model**: Newtonian fluid
- **Boundary conditions**
  Inlet: flat velocity profile derived from averaged physiological flow-rate curve
  Outlet: zero-pressure
  Wall: no-slip condition



The bent configuration was drawn according to real bent configuration of FPA.
The **knee-flexion movement** was obtained by imposing the movement *x(t)* on each nodes of the fluid grid.

- **Solver**: incompressible flow solver (ICFD) implemented in the finite element solver **LS-DYNA (ANSYS, Canonsburg, PA, USA)**.

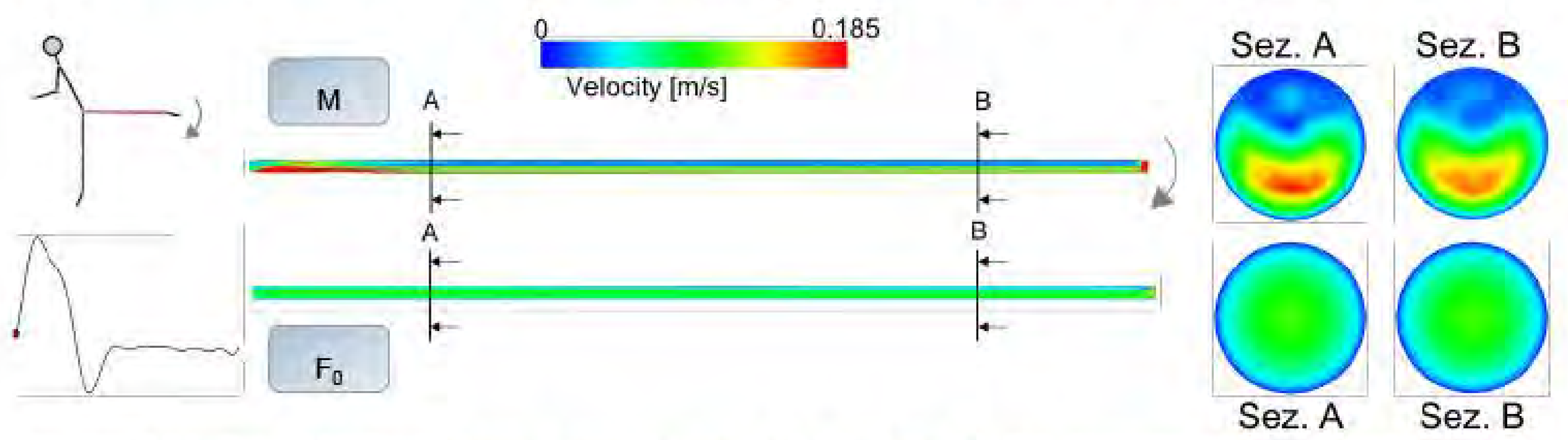
Two main scenarios were investigated:
- ✓ FIXED-WALL cases with Eulerian grids at 0-, 13-, 45-, 58- and 90- degrees flexion configurations.
  → **Models F_0, F_{13}, F_{45}, F_{58}, F_{90}**
- ✓ a MOVING-WALL case, with hip- or knee-flexion sinusoidal movement and realistic walking movement imposed on the grid.
  → **Model M**

Comparison was performed using **META post processor 19.0.2 (BETA CAE Systems, Luzern, CH)** for **velocity profiles** and **WSS-based descriptors**: time-averaged shear stress (TAWSS), the oscillatory index (OSI) and the relative residence time (RTT).

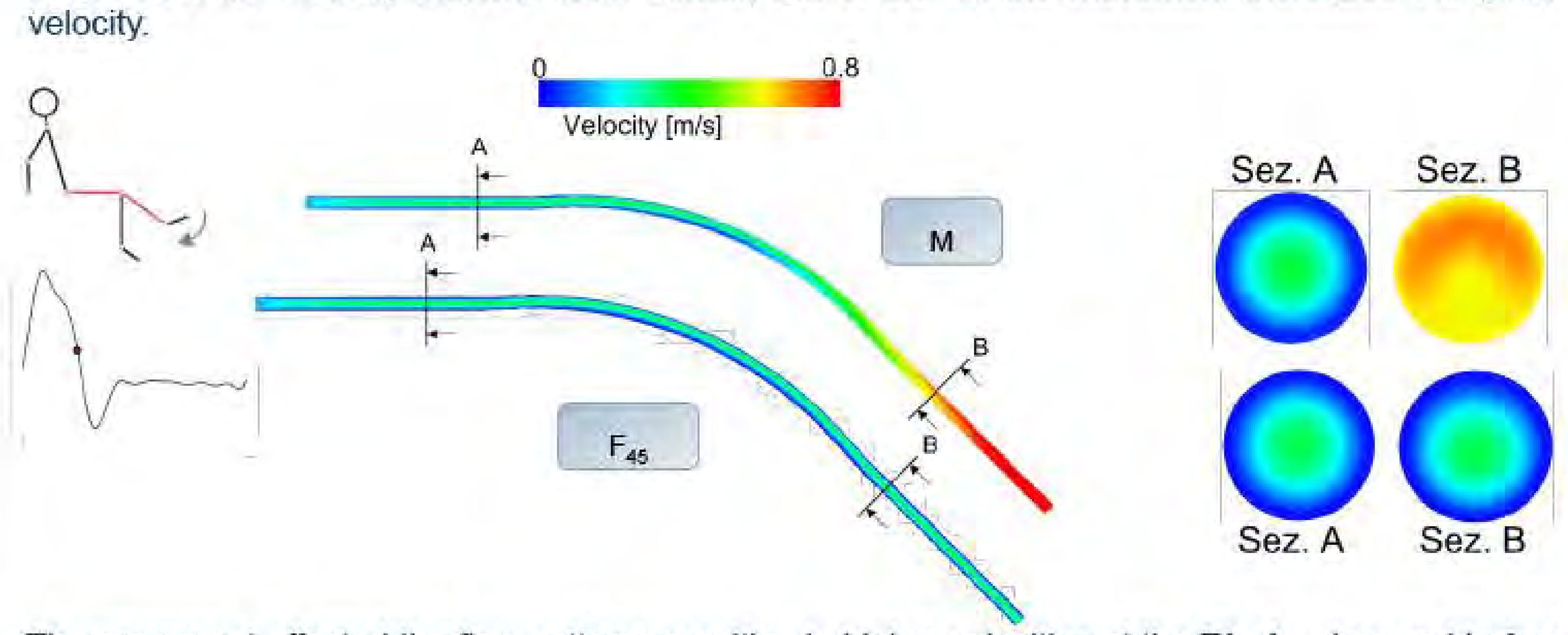
RESULTS

VELOCITY PROFILES

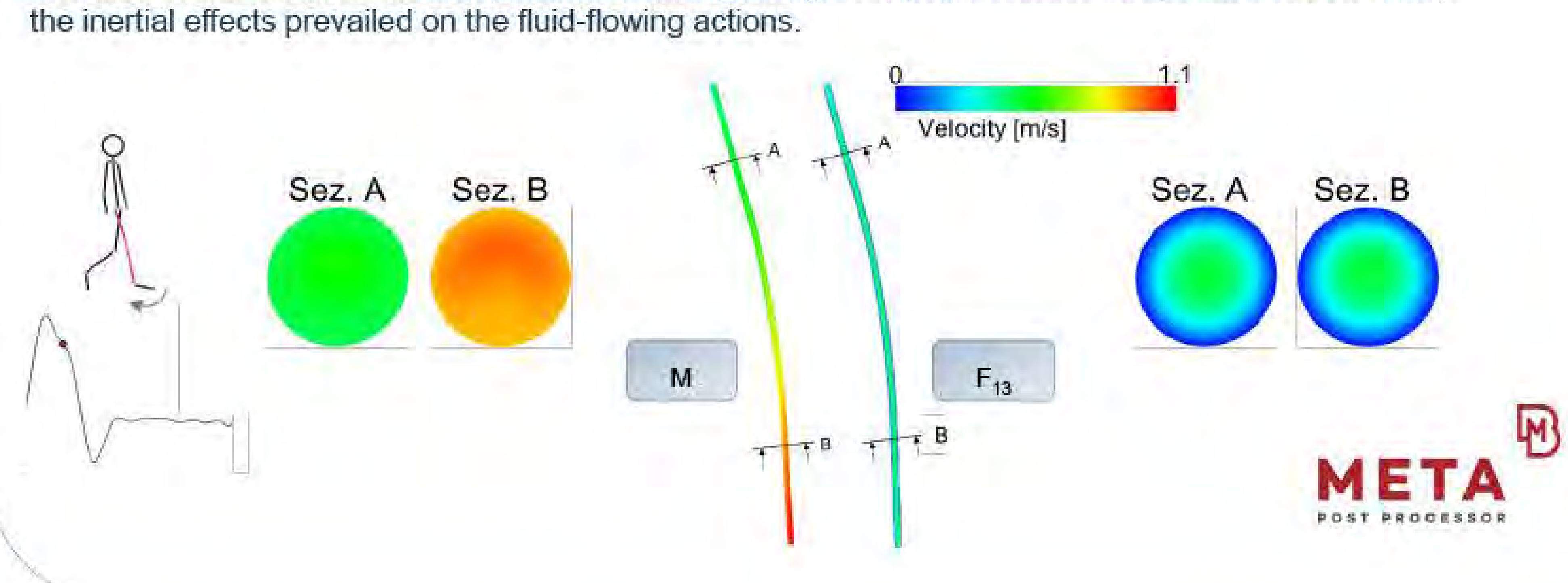
The movement affected the flow patterns resulting in higher velocities at the TA portion.



In the SFA the velocity patterns were similar, but in the TA the movement increased the peak velocity.

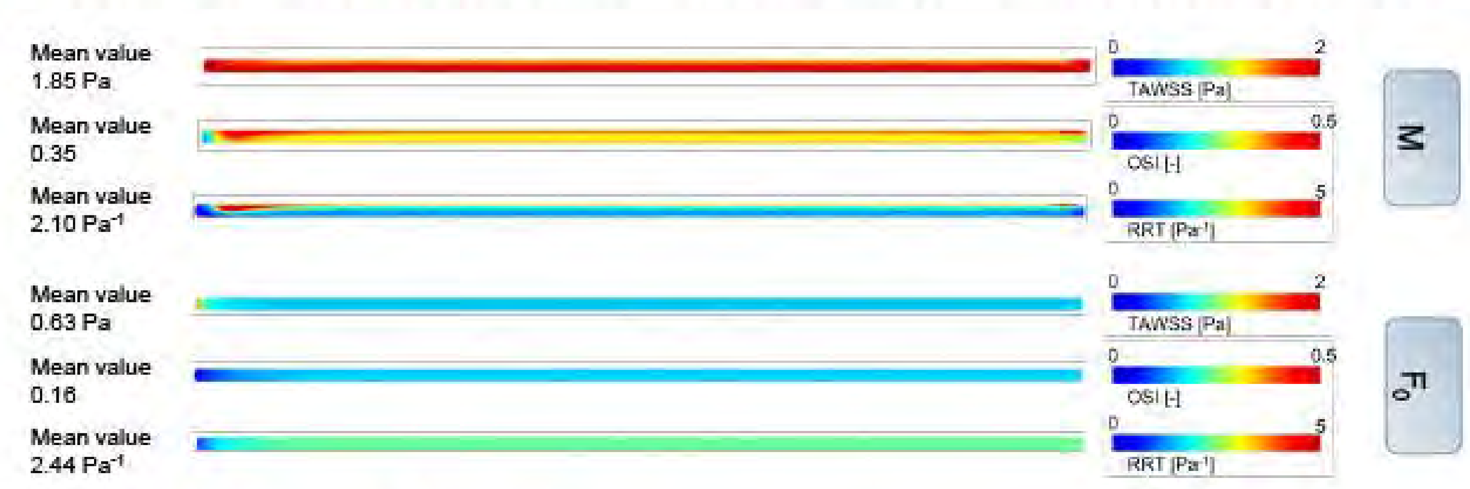


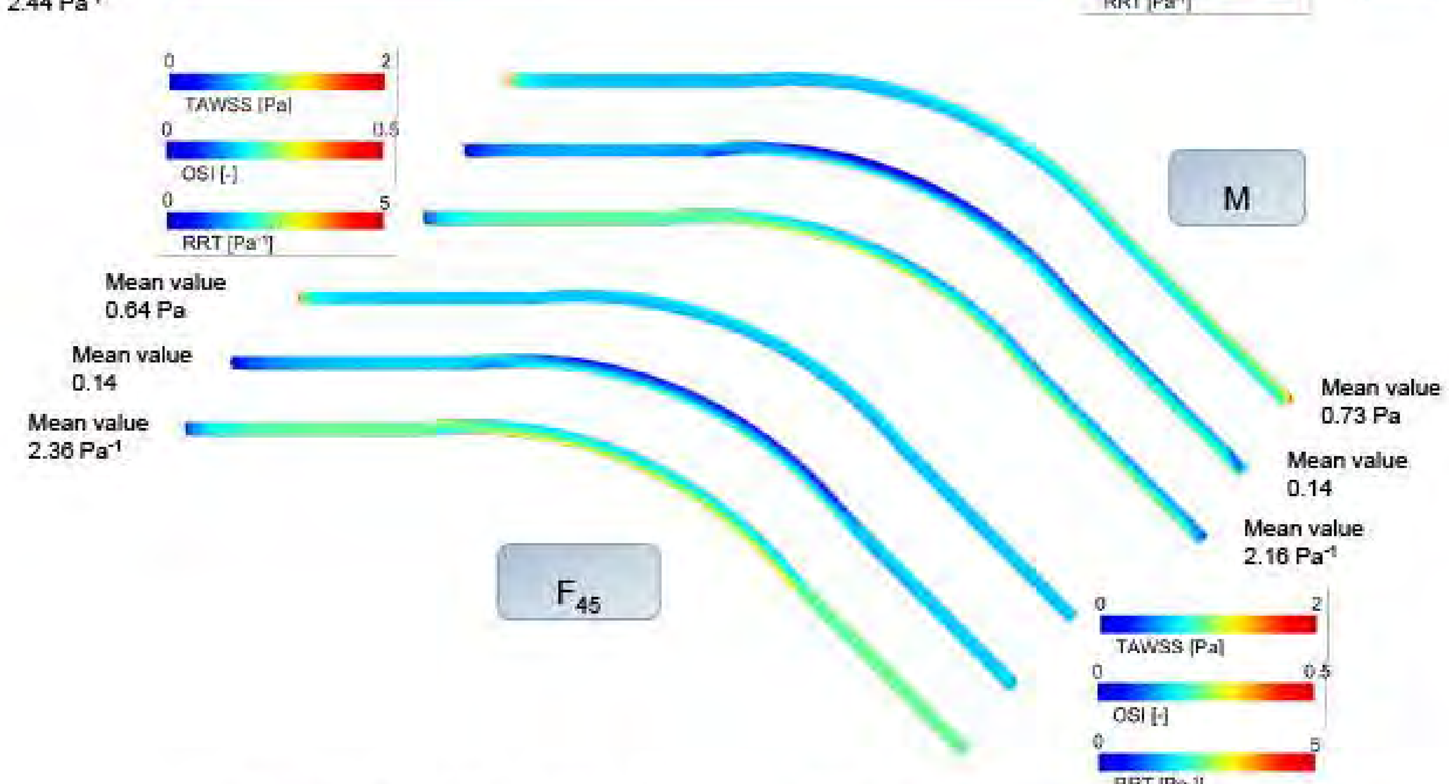
The movement affected the flow patterns resulting in higher velocities at the TA. As observed before, the inertial effects prevailed on the fluid-flowing actions.

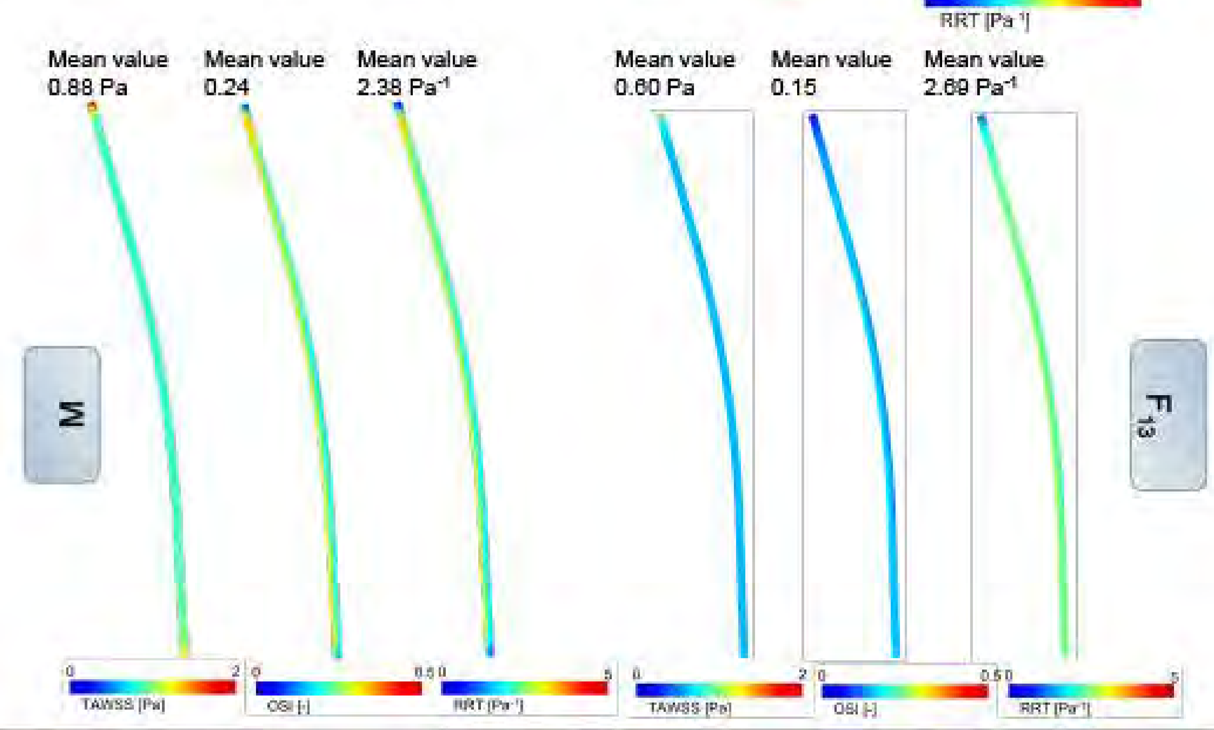


WSS-BASED DESCRIPTORS

- TAWSS and OSI are increased in **M** (hip flexion and walking) compared to **F_0** and **F_{13}**.
- TAWSS pattern of **M** (knee flexion) was qualitatively similar to **F_{45}** for SFA and PA.







CONCLUSIONS

The hemodynamics of the idealized FPA model resulted to be widely affected by the movement applied at the vessel wall. In the fixed-wall analysis, WSS varied between the FPA straight and bent configurations, **suggesting that patient-specific simulations in only one configuration cannot represent the actual fluid dynamics**. Thus, moving-boundary CFD simulations seem to be a better approach to analyze the FPA hemodynamics.

ACKNOWLEDGMENTS

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