A CFD manikin with a thermo physiology model

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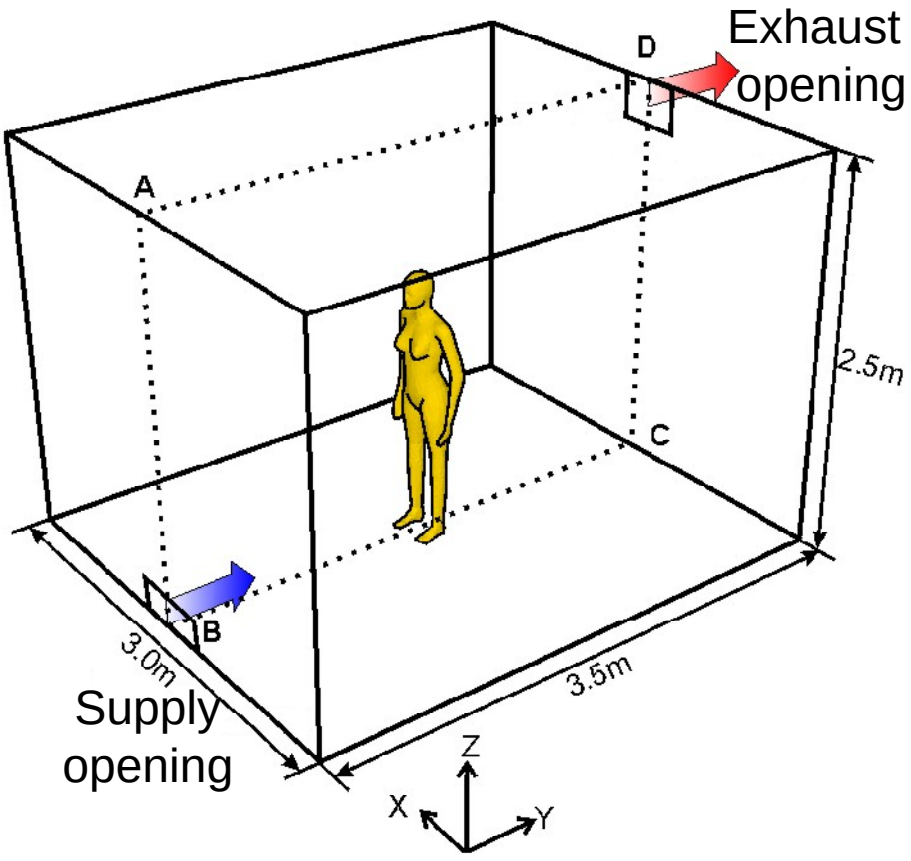
Outline

- Detailed measurement of velocity and temperature fields around an experimental thermal mannequin with uniform sensible heat generation
- Thermo physiology model with simplified human shape model however with detailed heat transfer model within body
- The difference between the microenvironment around a computational mannequin
- Since the skin temperature varies with the microenvironment, it becomes a bit difficult to obtain the CFD solutions

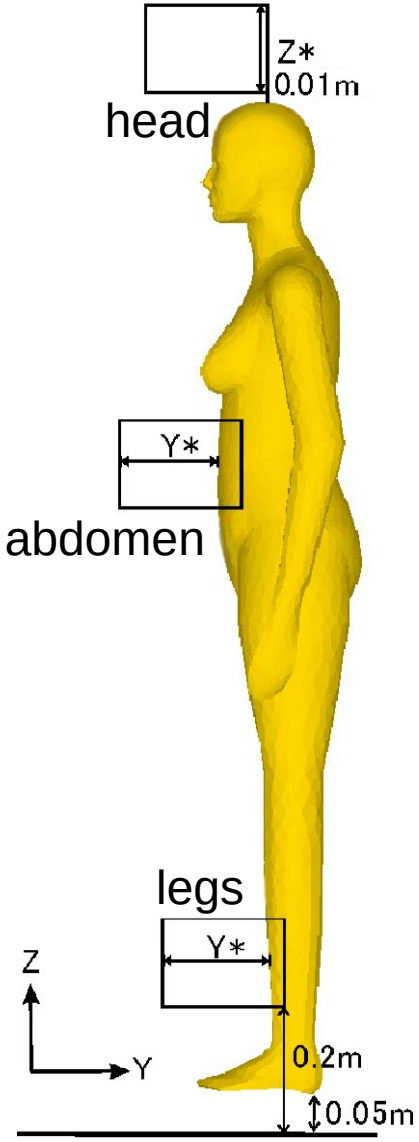
Displacement Ventilation Case

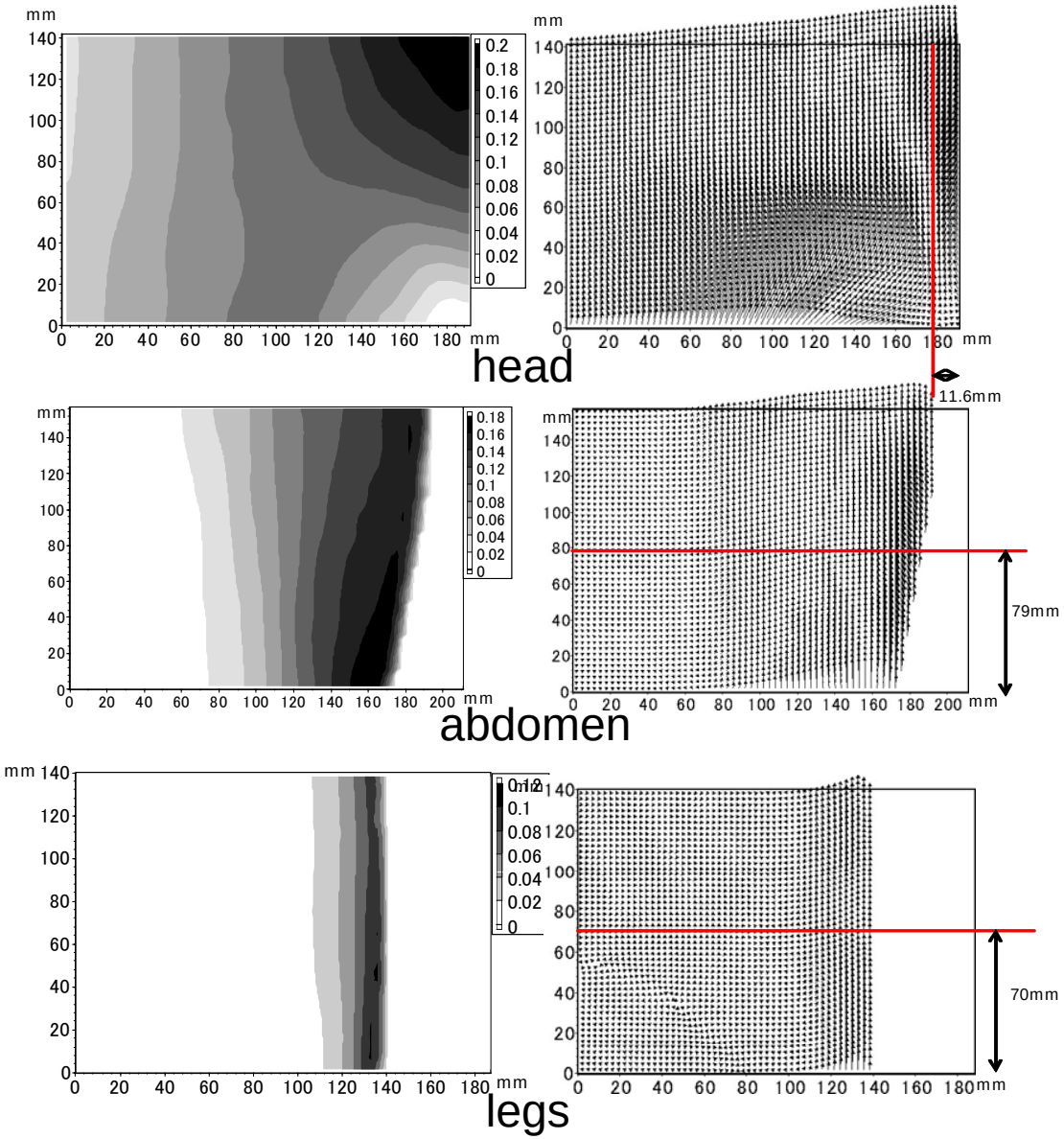


< Condition of experiment >

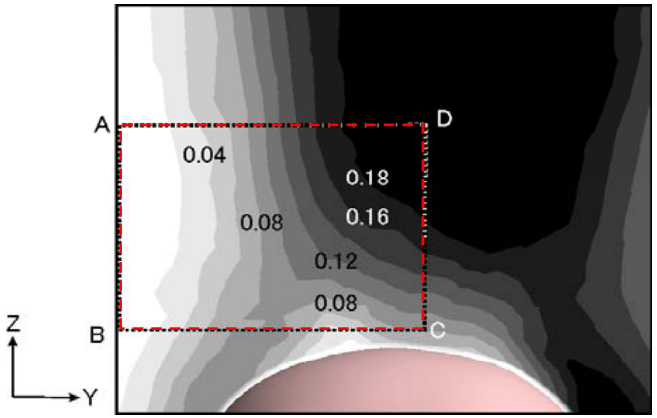
1. Test Room Size:
   0.3m x 3.5m x 2.5m
2. Supply Opening Condition:
   1) Velocity: 0.182m/s
   2) Size : 0.4m(w) x 0.2m(h)
   3) Temperature: 21.8 C
3. Exhaust Opening Condition:
   Size : 0.3m(w) x 0.3m(h)
4. Thermal Manikin Condition:
   76W (Area: 1.471m^2, 51.6W/m^2)

PIV Measurement Results

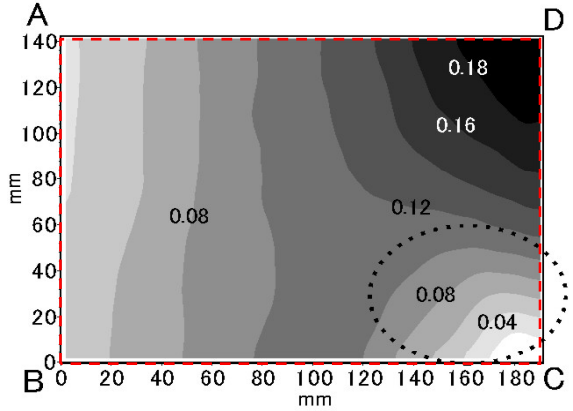




Comparison with former analysis

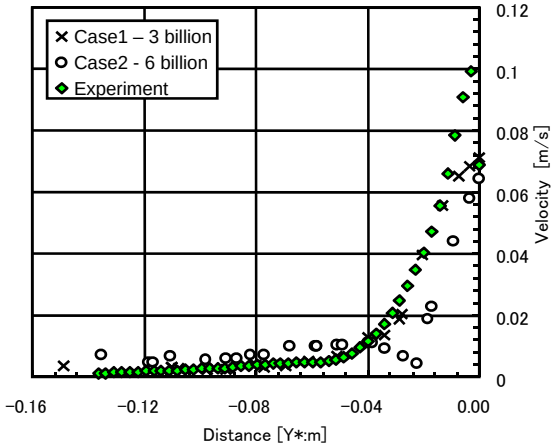


(a) CFD results : Case 2 – 6 billion meshes

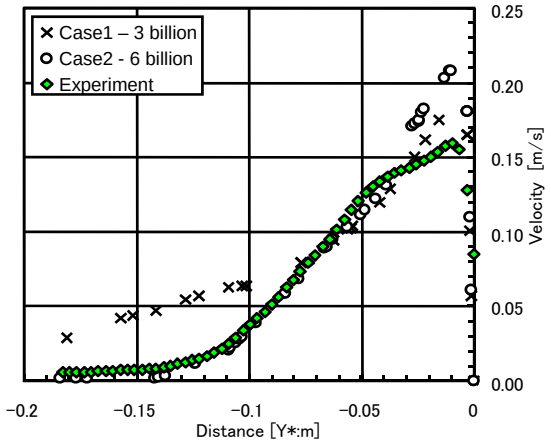


(b) PIV results : ABCD area in figure (a)

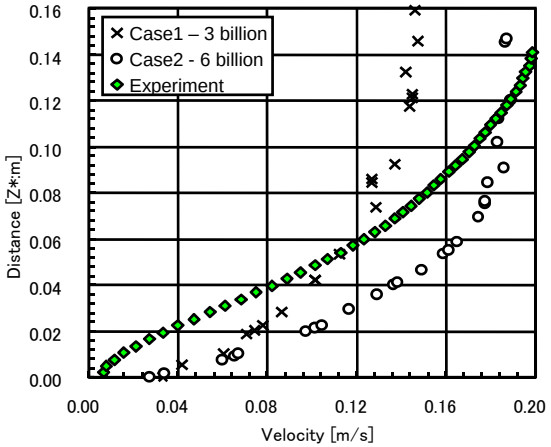
Scalar velocity distribution (Head, YZ) [m/s]



(a) Legs



(b) Abdomen



(c) Head

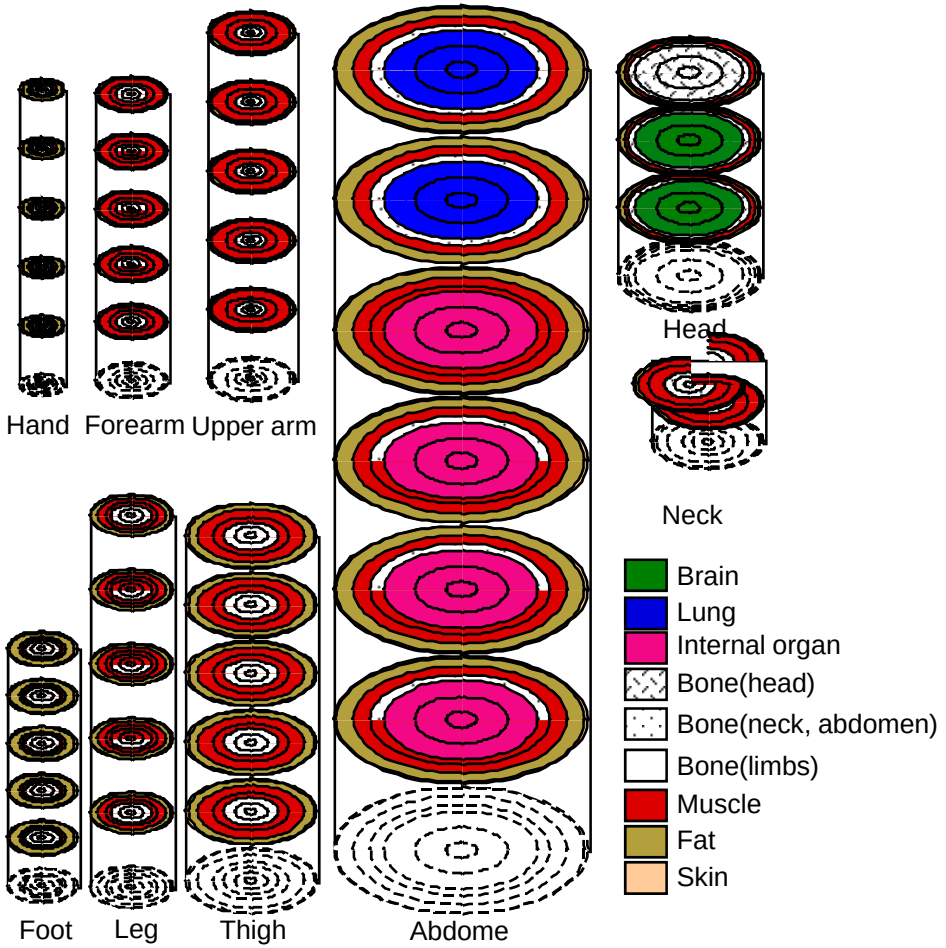
Scalar velocity values (Head, YZ) [m/s]

Characteristic of Sakoi Model (1)

We developed the human thermal model for *nonuniform* thermal environments

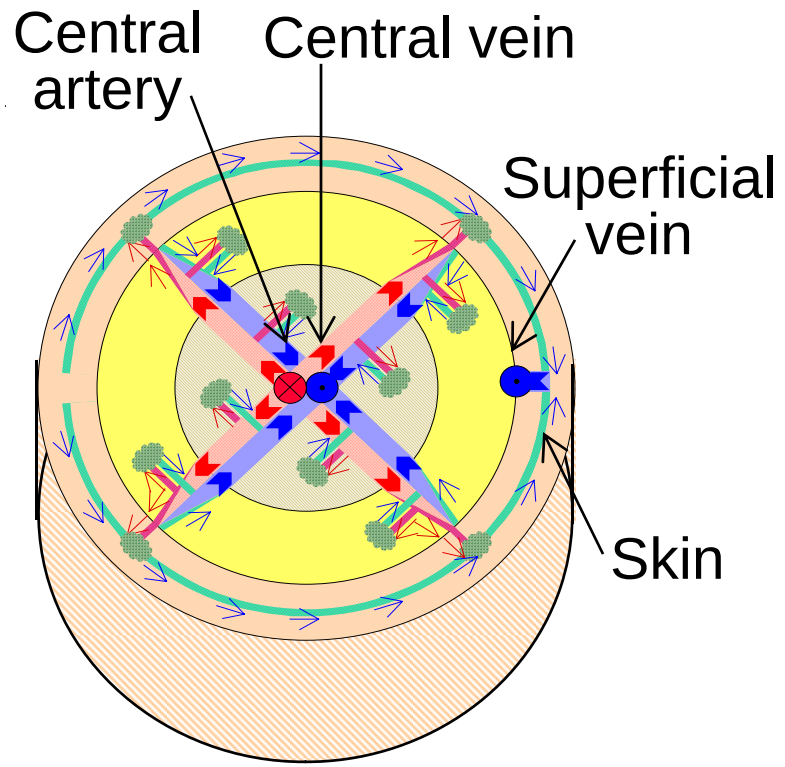
1. Inputs of 3D environmental parameter
2. Heat transfer characteristics depending on thermal conduction.
   (locations and configuration of tissue compositions)

Referring to the Smith model (1991), thermal conduction and heat production inside the tissue element are analyzed based on the Finite element method (Galerkin method).

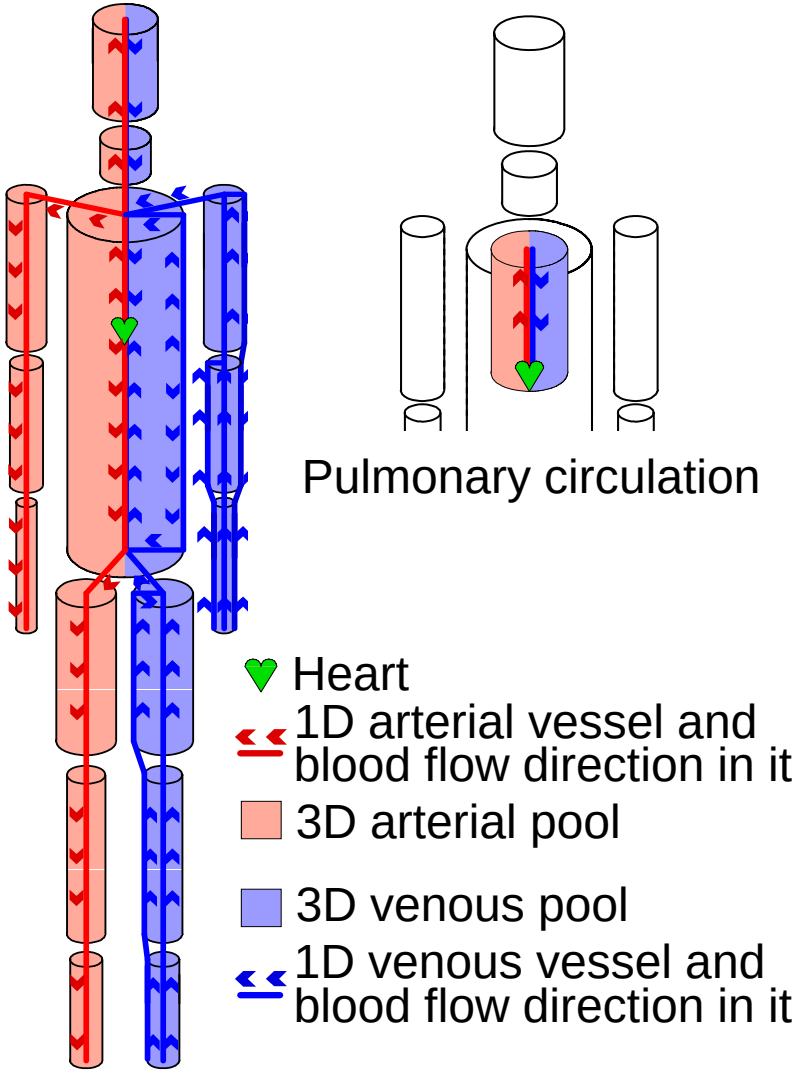


Components of human thermal model
Based on Smith model (1991)

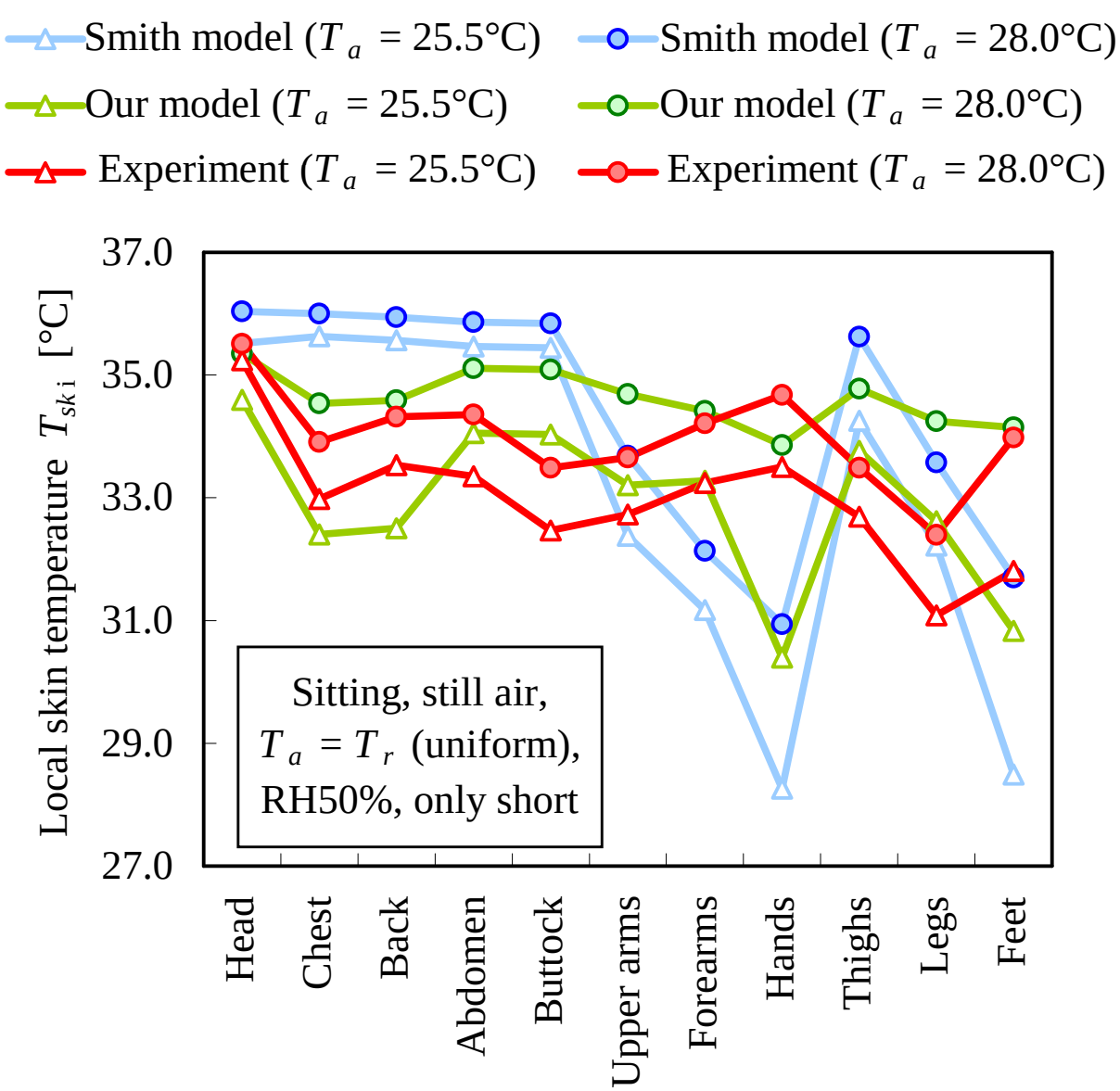
Characteristic of Sakoi Model (2)

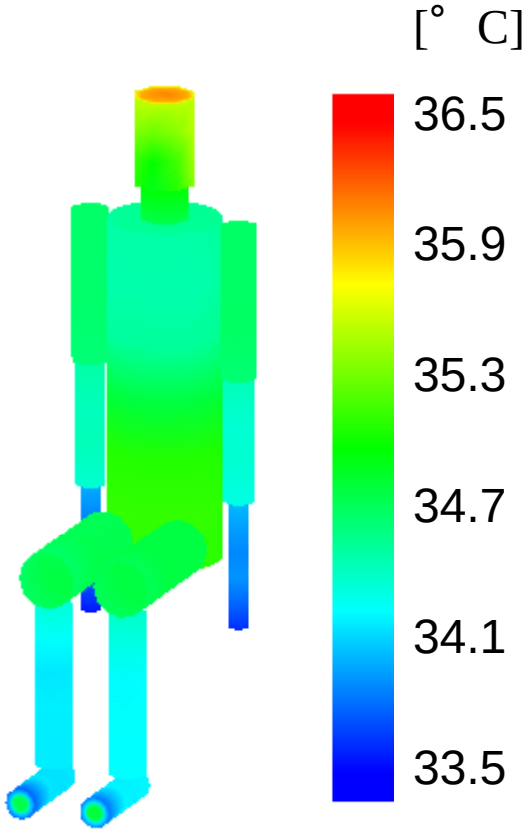


An example of blood circulation setting (**Cross sections** of the upper arms, thighs, and legs)



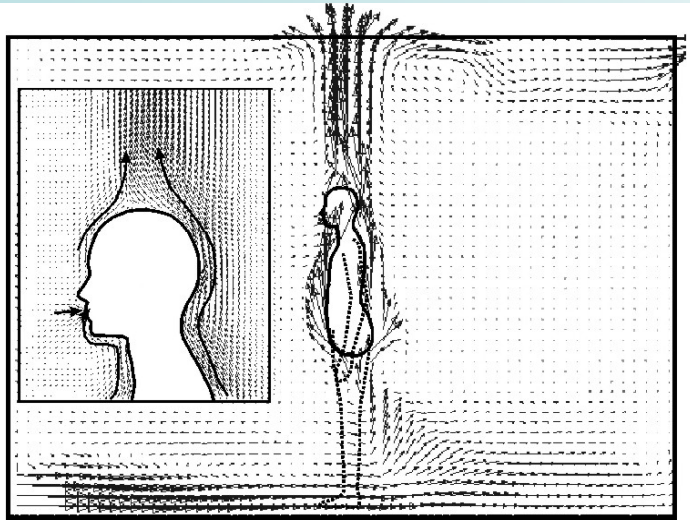
Comparison of calculated and measured local skin temperatures



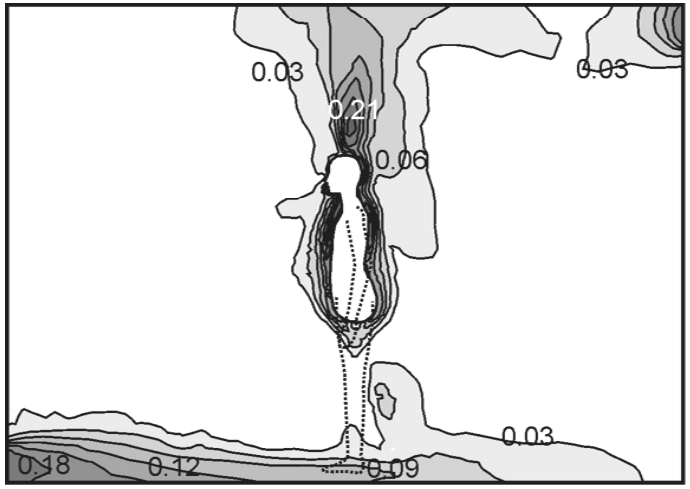


Calculated skin temperature distribution at T_a = 28° C

Former studies and CFD with Sakoi model

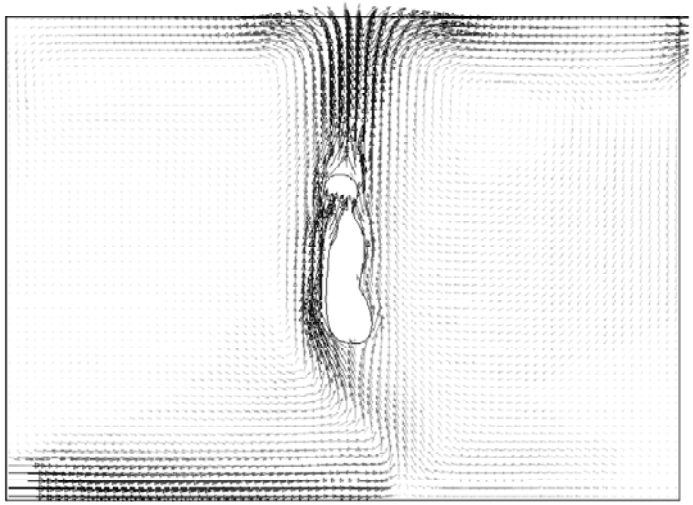


(a) Velocity vectors



(b) Scalar velocity distribution

Former studies



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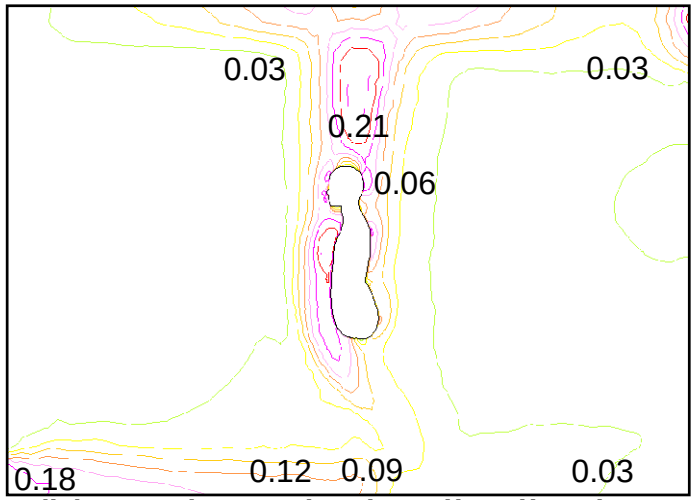
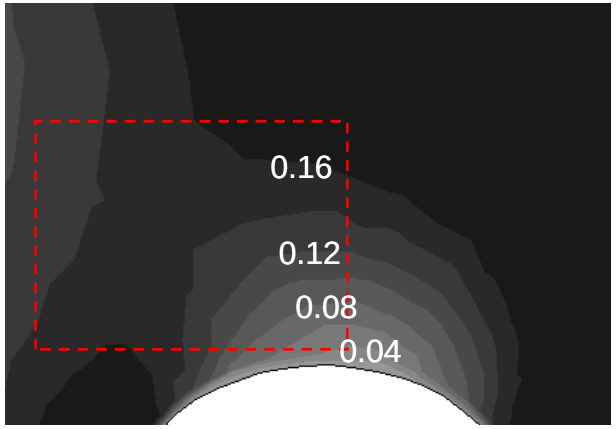


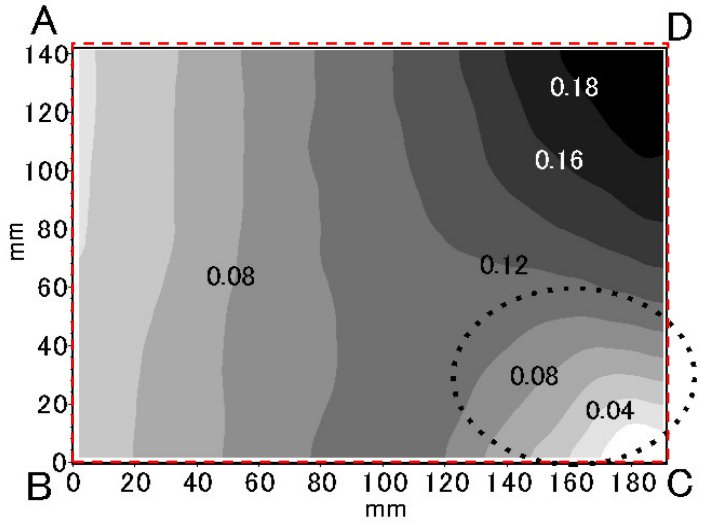
(b) Scalar velocity distribution

Analysis with Sakoi model

CFD with Sakoi model and PIV measurement



(a) CFD results



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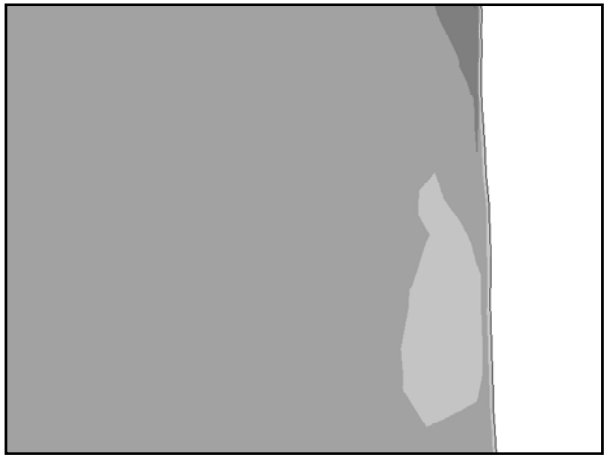

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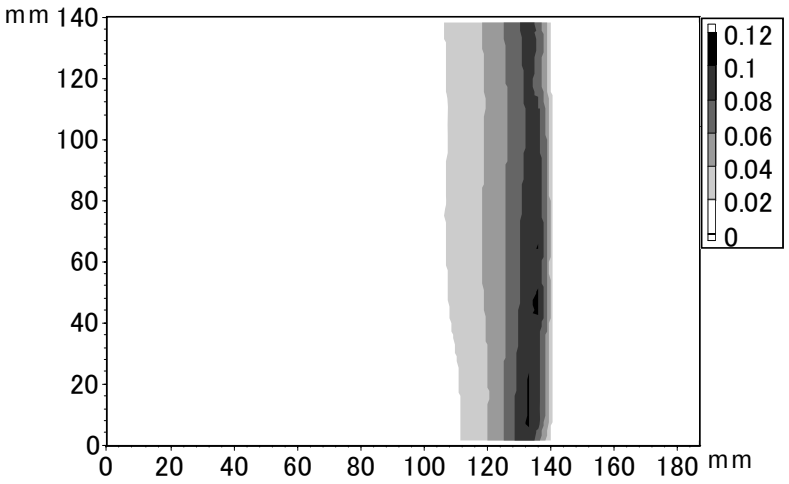
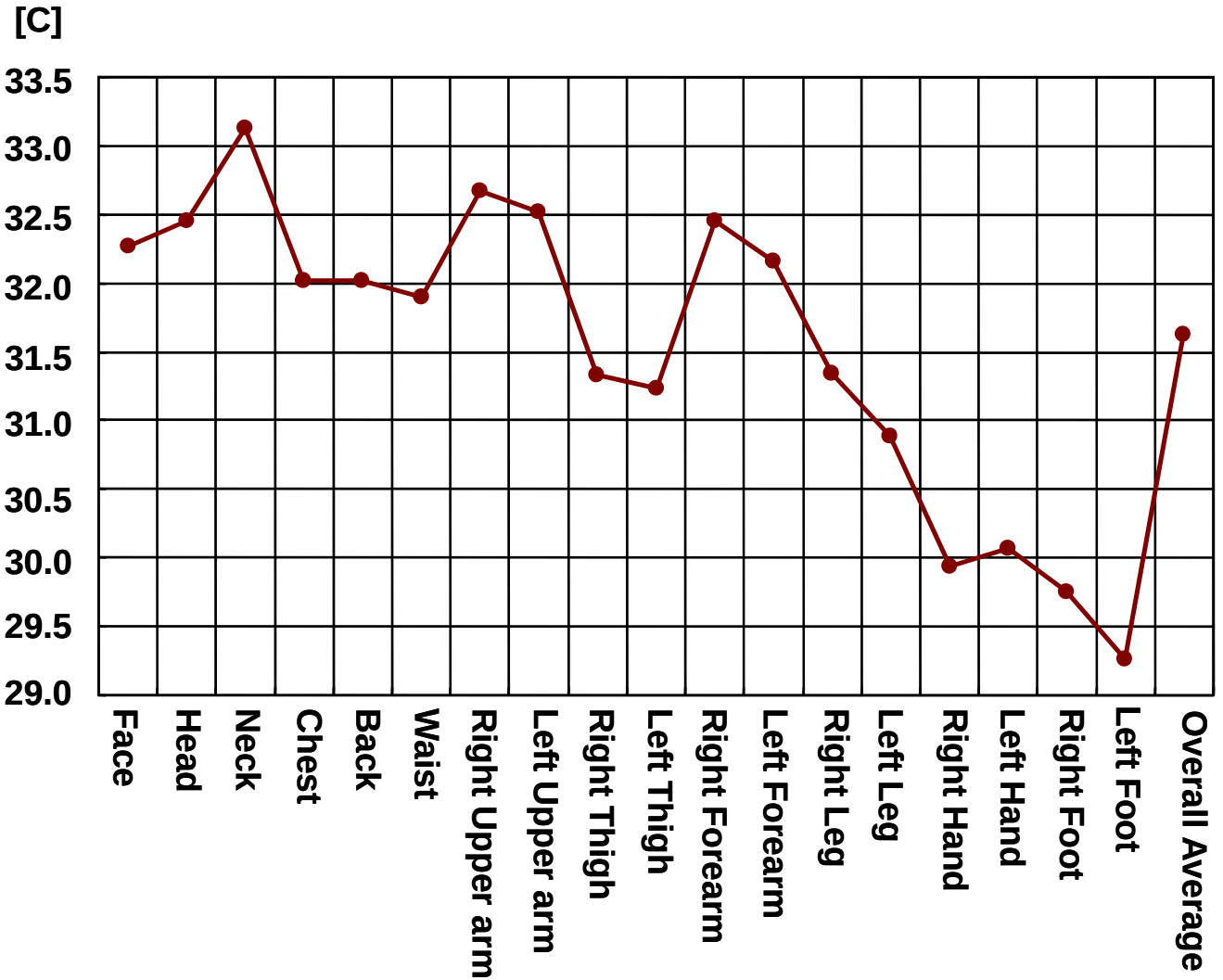


(b) PIV results

Scalar velocity distribution (Leg, YZ) [m/s]

Skin Temperature Distribution



Remained Works

- Are there clear differences on the microenvironment around a computational mannequin between the simple uniform heat generation model and the sophisticated thermo physiology model?
- There are still few works which connect the human thermal sensation with the skin temperature and heat transfer rate distributions even though many personal cooling systems utilize partial cooling of human body
- The detailed analysis of the sensible and latent heat transfer through clothing still difficult for part by part of the body, in particular ventilation effect within the clothing part by part is quite difficult.