Designing Local Radiant Heating Devices for Different Body Parts: Effects on Skin Temperature

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Research background

Starting point

- Our test facility was designed for the experiments on thermal comfort and occupant behavior research
- Effects of radiant ceiling heating with regard to the overall and local thermal sensation
- A review of local radiant heating systems and their effects on thermal comfort and sensation

Challenge

- Existing local thermal comfort and sensation models

Research background

Project objective

Development of an advanced comfort model that considers both radiation and convection heat transfer

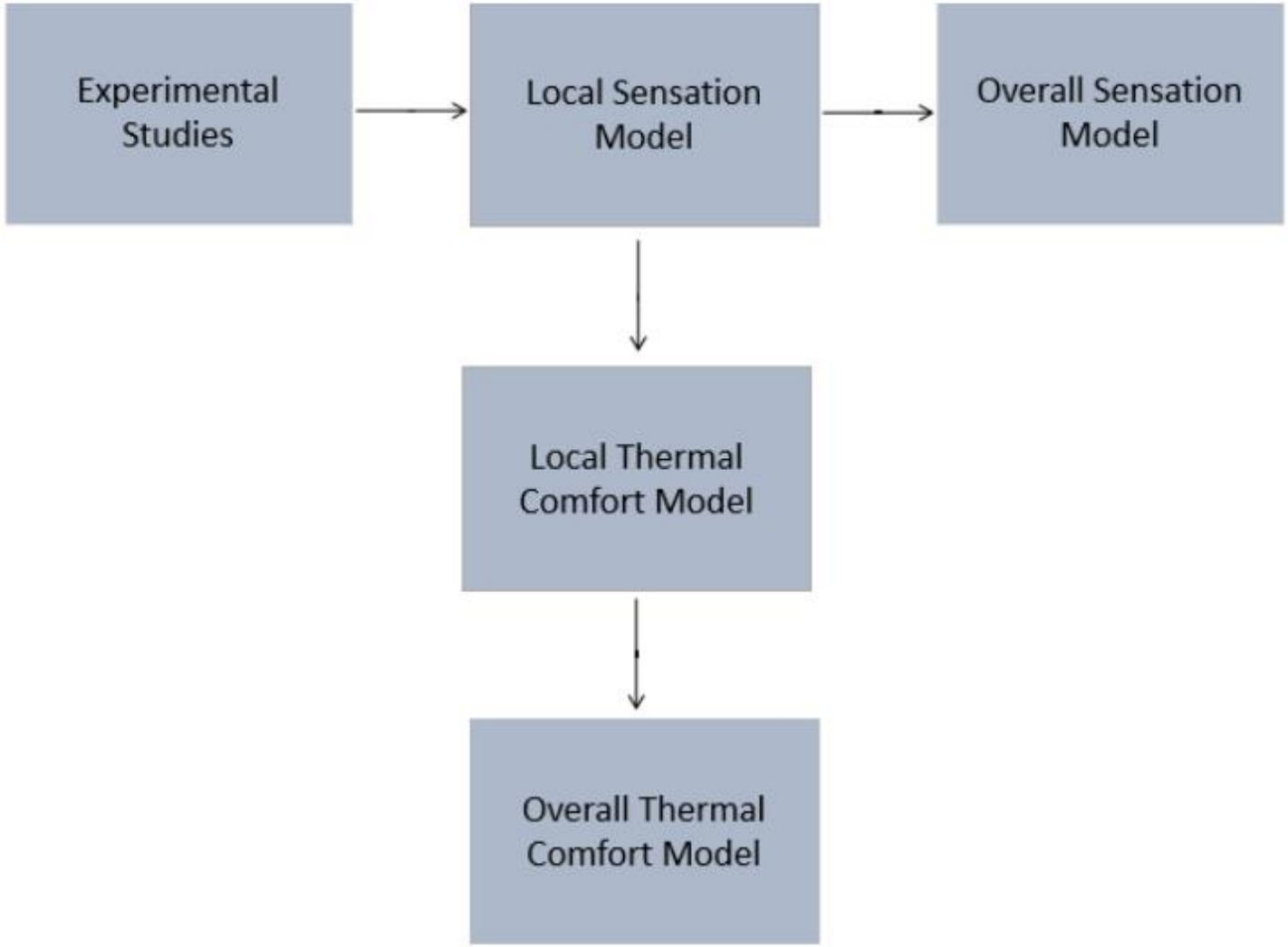
- To improve an existing comfort model (Berkeley Comfort Model)
- Development of the sub-model for radiant heat exchange between by correlating subjective and objective data
- Enhancement of Berkeley model by including the sub-model for radiant heat exchange between the human body parts and their thermal environment.

Methods

- We need to obtain regression coefficients for different body parts.

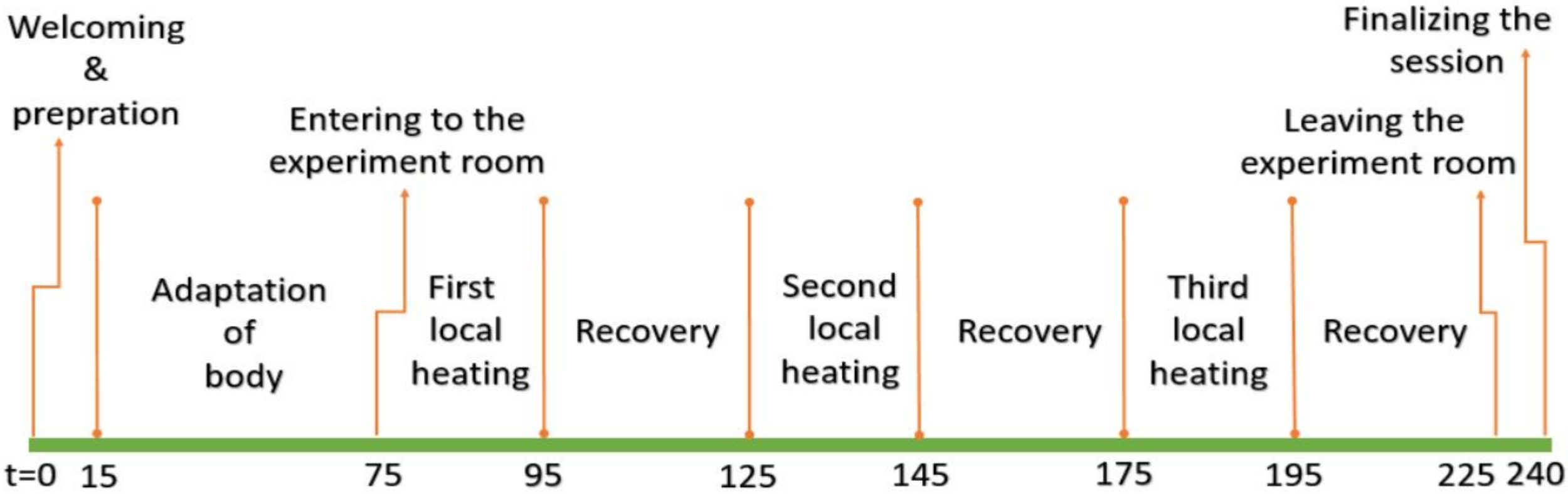
- The obtained regression coefficients will be implemented to improve the overall thermal sensation/comfort models

Methods


Experimental Studies
Local Sensation Model
Overall Sensation Model
Local Thermal Comfort Model
Overall Thermal Comfort Model

Methods

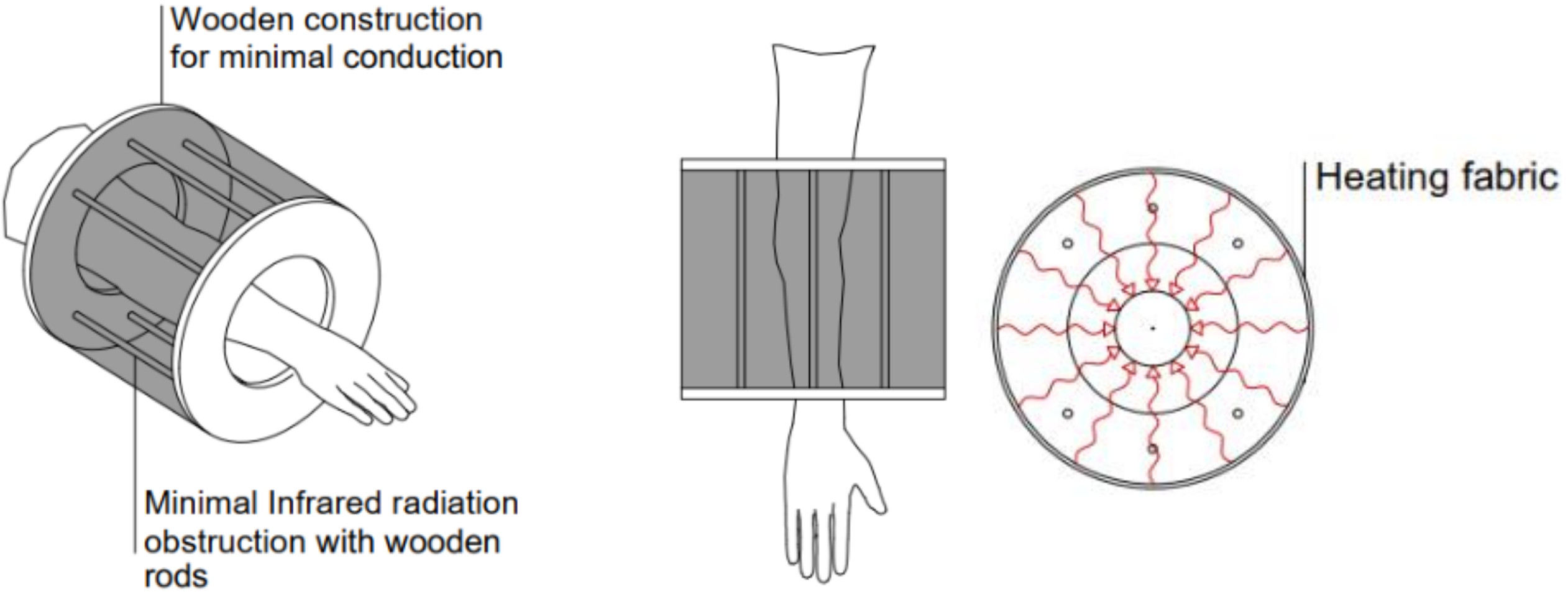
- Transient/asymmetric, steady/asymmetric and steady/uniform conditions
- Operative temperature of 19.5 °C



Air-sleeve design for different body parts

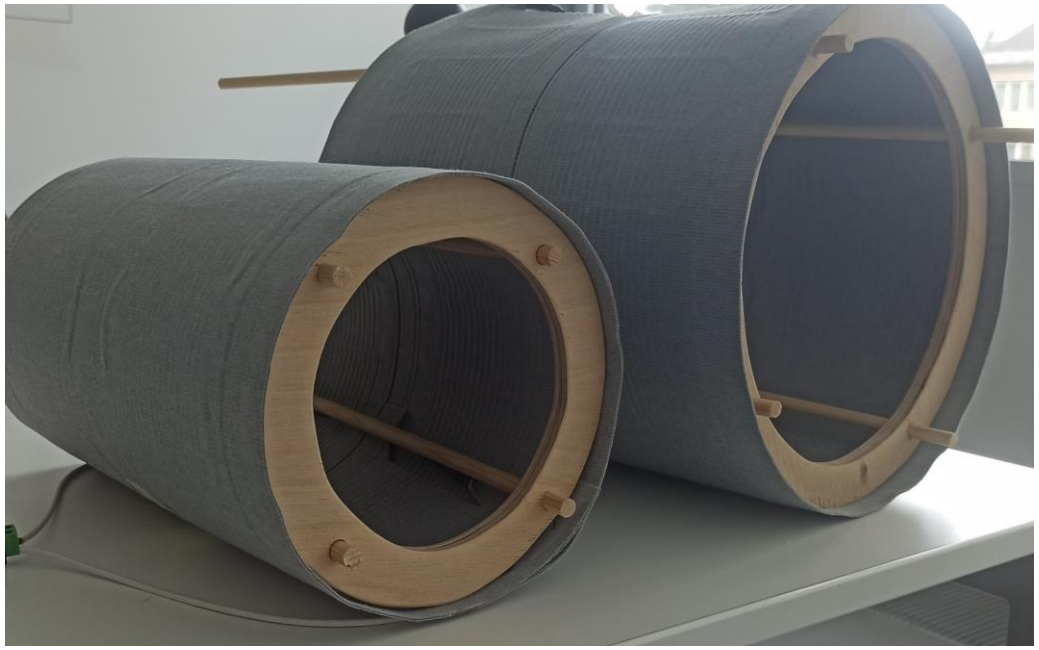
Zhang, 2003

Local radiant heating devices



Local radiant heating devices

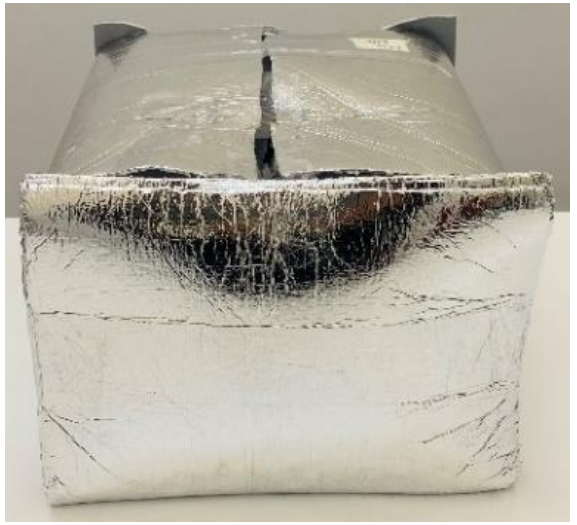
Arm



Leg

Local radiant heating devices

Hand



Foot

Local radiant heating devices

Neck

Head

Local radiant heating devices

Chest

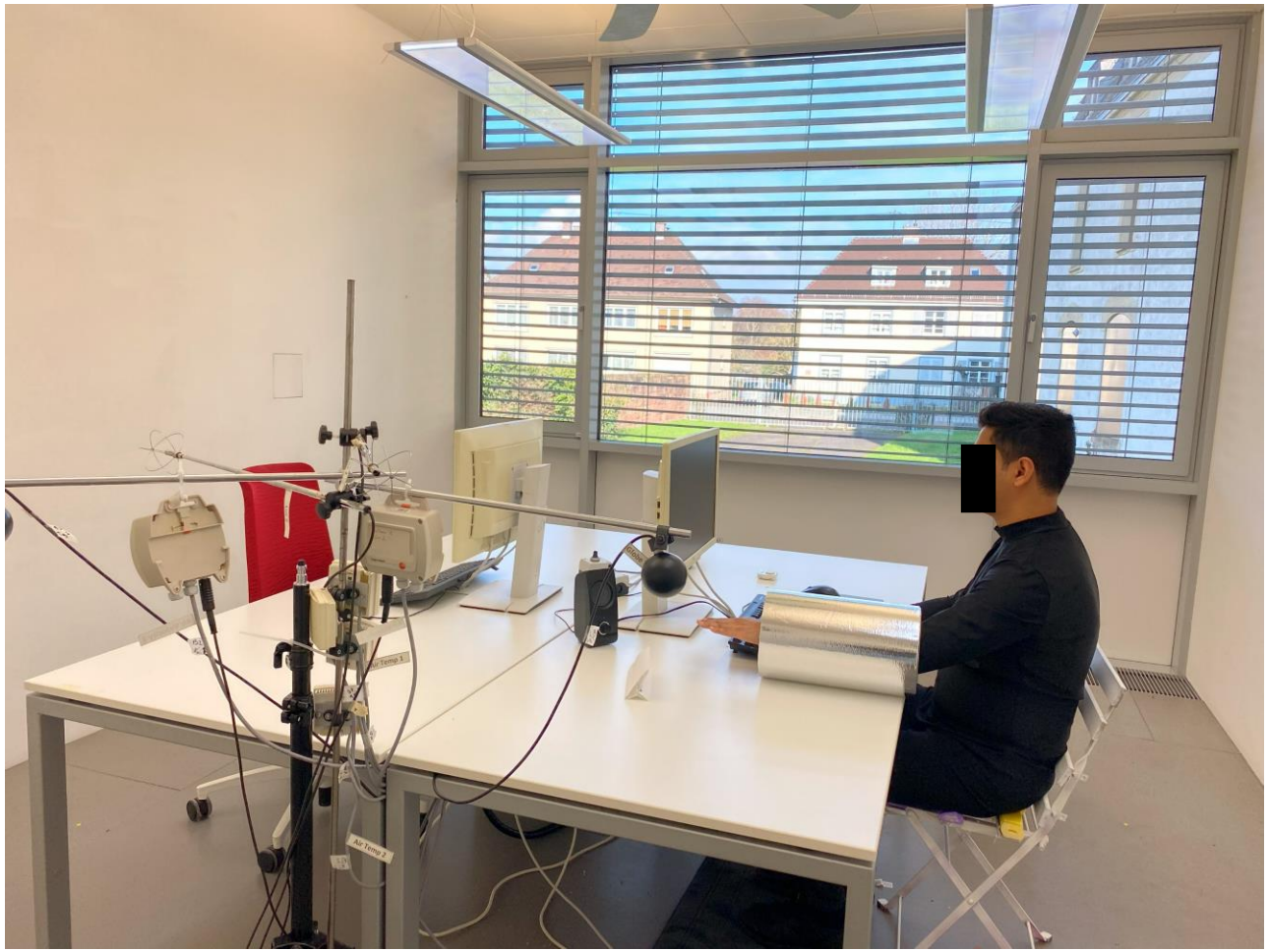
Pelvis

Face

Data collection

- 10 voluntary students (5 male and 5 female)
- Local heating using radiant fabrics at 18 body parts – face, head, neck, chest, back, pelvis, left and right upper arms, left and right lower arms, left and right hands, left and right thighs, left and right lower legs, and left and right feet
- Each subject will participate 6 times

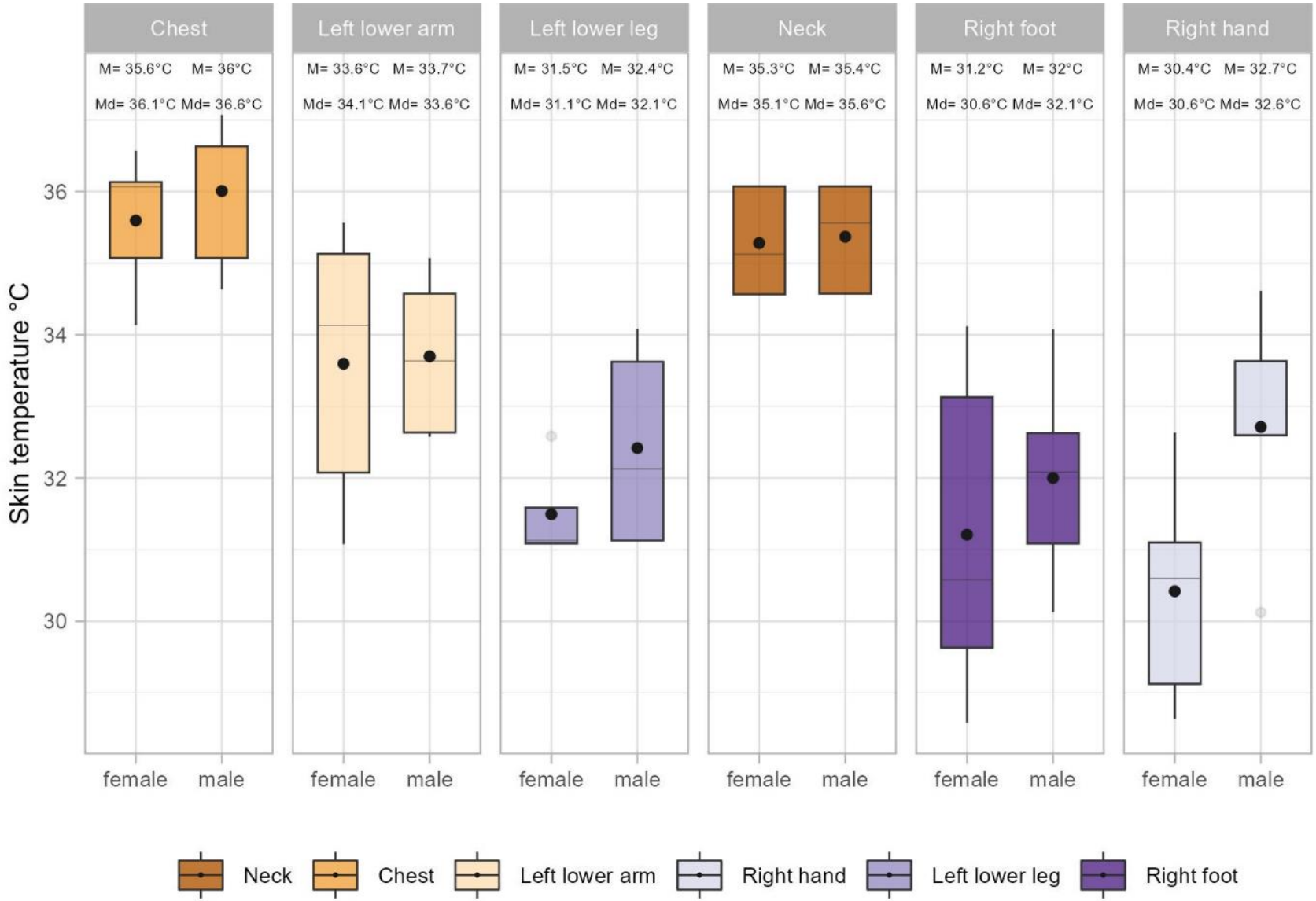
Data collection



Data collection

	Male	Female	All
Age (years)	26.0 (±4.2)	27.2 (±5.3)	26.6 (±4.5)
Height (m)	181.6 (±3.0)	170.4 (±5.0)	176.0 (±7.1)
Weight (kg)	78.7 (±7.3)	68.0 (±10.2)	73.3 (±10.1)
BMI	23.9 (±2.9)	23.3 (±2.3)	23.6 (±2.5)

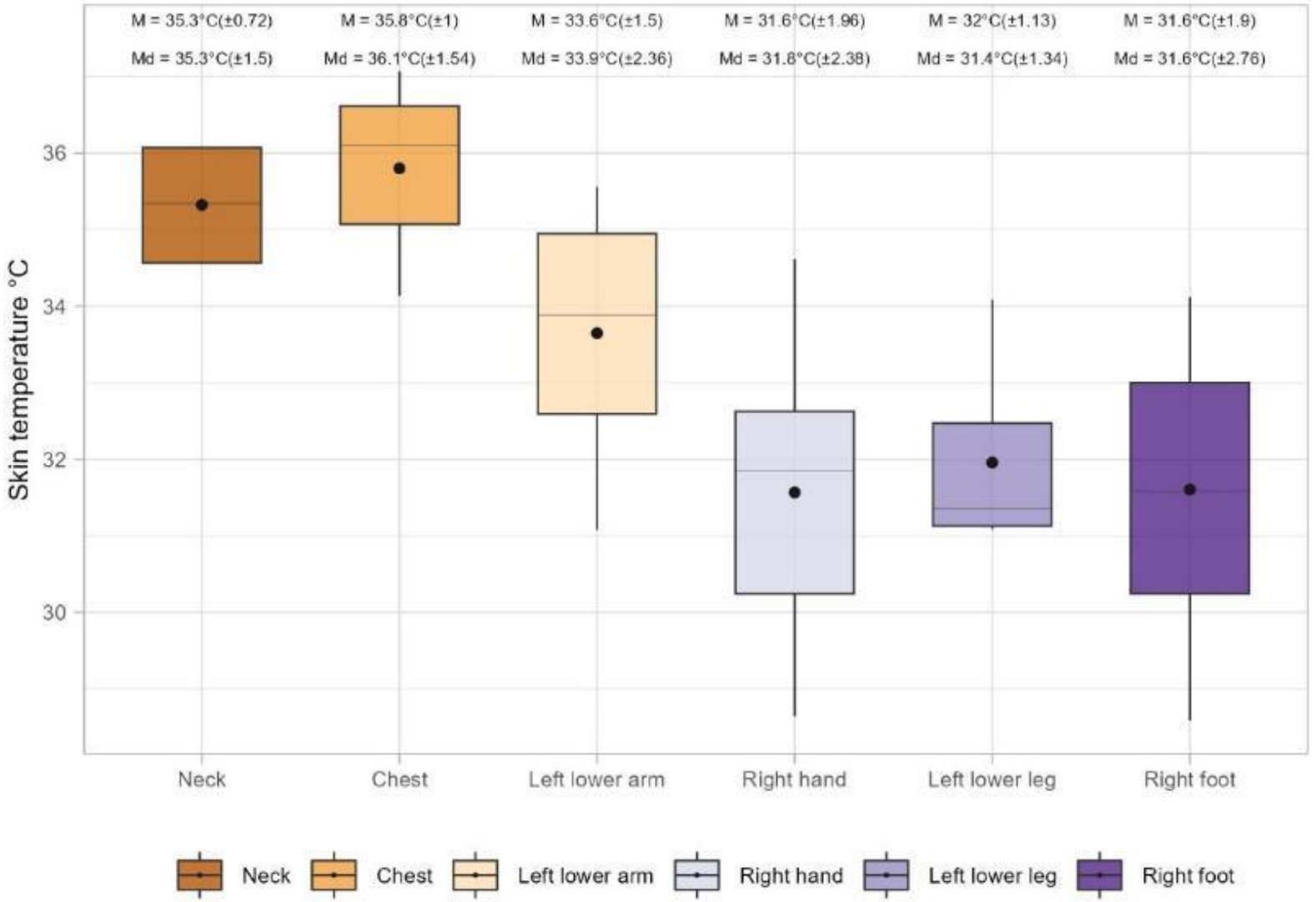
Results


Chest
M= 35.6°C M= 36°C
Md= 36.1°C Md= 36.6°C
Left lower arm
M= 33.6°C M= 33.7°C
Md= 34.1°C Md= 33.6°C
Left lower leg
M= 31.5°C M= 32.4°C
Md= 31.1°C Md= 32.1°C
Neck
M= 35.3°C M= 35.4°C
Md= 35.1°C Md= 35.6°C
Right foot
M= 31.2°C M= 32°C
Md= 30.6°C Md= 32.1°C
Right hand
M= 30.4°C M= 32.7°C
Md= 30.6°C Md= 32.6°C
Skin temperature °C
36
34
32
30
female
male
Neck
Chest
Left lower arm
Right hand
Left lower leg
Right foot

Results

Body Part	Male		Female		P-value
	Median ± iqr	Mean ± sd	Median ± iqr	Mean ± sd	
Neck	35.6±1.5	35.4±0.8	35.1±1.5	35.3±0.8	0.857
Chest	36.6±1.6	36.0±1.1	36.1±1.1	35.6±1.0	0.545
Left lower arm	33.6±1.9	33.7±1.1	34.1±3.1	33.6±2.0	0.922
Right hand	32.6±1.0	32.7±1.7	30.6±2.0	30.4±1.6	0.058
Left lower leg	32.1±2.5	32.4±1.4	31.1±0.5	31.5±0.7	0.227
Right foot	32.1±1.5	32.0±1.5	30.6±3.6	31.2±2.3	0.545

Results


M = 35.3°C(±0.72)
Md = 35.3°C(±1.5)
M = 35.8°C(±1)
Md = 36.1°C(±1.54)
M = 33.6°C(±1.5)
Md = 33.9°C(±2.36)
M = 31.6°C(±1.96)
Md = 31.8°C(±2.38)
M = 32°C(±1.13)
Md = 31.4°C(±1.34)
M = 31.6°C(±1.9)
Md = 31.6°C(±2.76)
Skin temperature °C
36
34
32
30
Neck
Chest
Left lower arm
Right hand
Left lower leg
Right foot
Neck
Chest
Left lower arm
Right hand
Left lower leg
Right foot

Results

Body Part	Present study	Olesen and Fanger, 1973	Zhang, 2003
Neck	35.3		35.8
Chest	35.8	34.5	35.1
Left lower arm	33.6	32.7	34.6
Right hand	31.6	33.5	34.4
Left lower leg	32	32.6	32.9
Right foot	31.6	32.2	33.3

Conclusions

- Using local radiant heating devices at ambient temperature of 19.5°C led to an increase in skin temperature (reached to the neutral skin temperature)
- Radiant heating panels heat only their surfaces, not the entire interior environment, they have high heating efficiency
- These systems have a quick response and can heat body parts in a short amount of time
- They use low voltage and because they work in a low temperature condition, the energy use is low