HSLU Hochschule Luzern

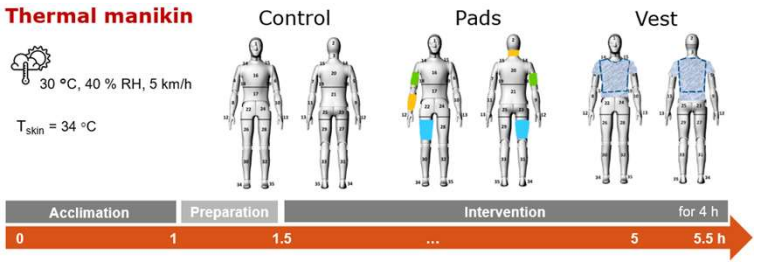
Technik & Architektur
Master's Thesis - Medical Engineering
Double Degree: FH Technikum Wien

FH University of Applied Sciences TECHNIKUM WIEN

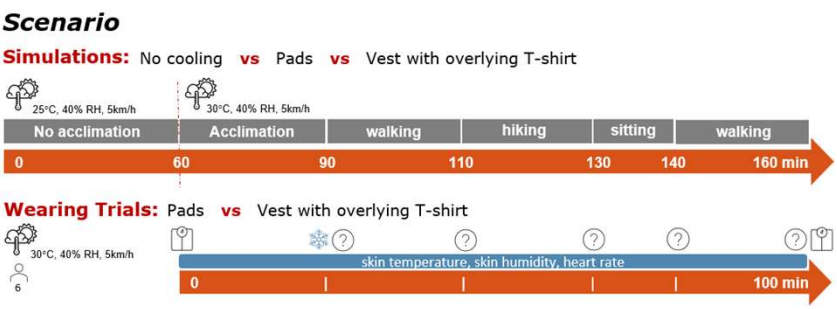
Master of Science in Engineering

Evaporative Cooling: Thermophysiological Effects on Body Areas

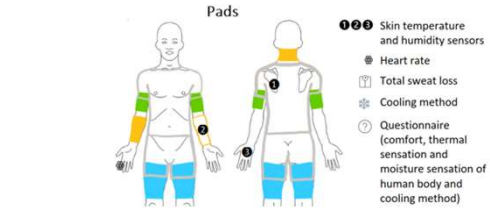
Insights from thermal manikin studies, thermophysiological simulations, and wearing trials



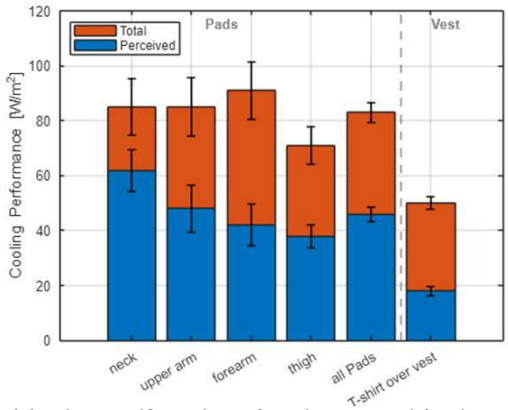
Procedure of thermal manikin measurement: Control (undressed manikin) and intervention (either uncovered pads or vest with overlying T-shirt)



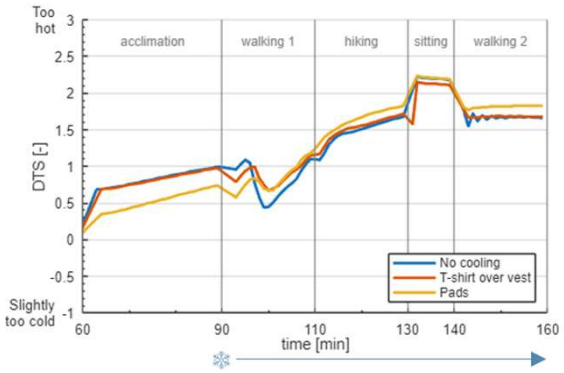
Procedure of Simulations and Wearing Trials



Measurement Parameters – Wearing Trial (Example: Pads)



Total (without self-insulation) and perceived (with self-insulation) cooling performance of pads and vest, quantified with thermal manikin experiments



Simulated dynamic thermal sensation: Scenario-dependent variation over time. (❄: Cooling application)

Problem
Climate change and more frequent heat waves increase health risks, particularly in vulnerable populations (older adults, spinal cord injuries), who are especially affected due to impaired thermoregulation. Evaporative cooling vests represent an established strategy to reduce heat strain and improve thermal comfort. They are simple to use, independent to any power source and provide long-lasting cooling. However, these systems (vests) are bulky, uncomfortable in sitting or lying positions, and not suitable for all body shapes. Localized cooling of thermosensitive areas (neck, arms, thighs, forearms) offers a less bulky and more adaptable alternative to torso cooling. Its effectiveness compared to torso cooling is not yet systematically studied. This gap forms the basis of the present work.

Solution Concept
This study compares localized evaporative cooling (neck, arms, thighs, forearms) with torso cooling. Cooling performance is assessed using thermal manikin measurements, numerical simulations of human thermoregulation, and wearing trials to capture physiological responses and subjective comfort. The aim is to determine whether extremity cooling can provide similar thermophysiological responses to torso cooling under an overlying T-shirt.

Results
Thermal Manikin: Multiple pads applied on the extremities achieved stronger local cooling than the vest with overlying T-shirt. Highest cooling effect was found at the neck, followed by the upper arm, forearm and thigh.
Simulations: Core temperature remained unchanged during cooling. Thermal sensation improved briefly after cooling. Pads reduced sweating but were slightly less comfortable than the vest.
Wearing Trials: Torso cooling was perceived as more comfortable, especially instantly after application and during recovery. Physiological outcomes were similar for extremity and torso cooling.

Abbreviations
RH: relative humidity
T_{skin}: skin temperature

Conclusion
Extremity cooling achieves effects comparable to torso cooling, offering a flexible alternative. Cooling and wearing comfort is most effective before the body starts to sweat. As a next step, the impact of evaporative cooling systems in real-world application scenarios needs to be investigated.

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