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## The Performances of Electrically Heated Vests (EHV) and Kinetic Vests (KV)


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### Background


- Cold weather garments are needed to protect the human body against cold stress in temp. below 10 °C (most likely below 0 °C).
- **Traditional cold weather clothing**
- Heavy, bulky
- Limit body activity, reduce finger dexterity and productivity



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### Background


- **Any solution?**
- ❖ Clothing with auxiliary heating
- ❖ Replace one (or more) layer traditional clothing



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### Background



- Heated clothing
- ❖ Electrical heated clothing
- ❖ Clothing with PCM
- ❖ Clothing with chemical substances
- ❖ Clothing with flow circulation



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### Background


- Heating elements:  
Electrical wires, conductive rubber, printed circuit heaters
- Carbon polymer heating elements
- High-tech conductive fibre
- Slim, light, washable
- No limitation on body movement

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### Background

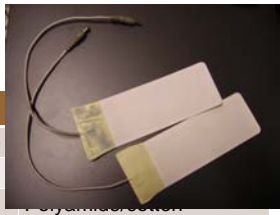


- In this energy-saving era, the energy efficiency becomes very important.
- The amount of energy benefitted from a heated garment is
- Heating power × heating efficiency



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### Methods


Study	Garments
1	Underwear (U)
	EHV (E)
	Uniform (U)
2	Underwear
	EHV
	Jacket
	Gloves
	Trousers
	Sports shoes

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### Methods

Study	Air temp. (°C)	Air velocity (m/s)	Manikin temp. (°C)	Manikin type
1	4.5±0.5	0.22±0.08	34.0	TORE
		0.44±0.09		
		0.66±0.09		
2	0±0.5	0.40±0.10	33.0	NEWTON
	-10.0±0.5			



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## Calculation

### • Heating efficiency $\eta$

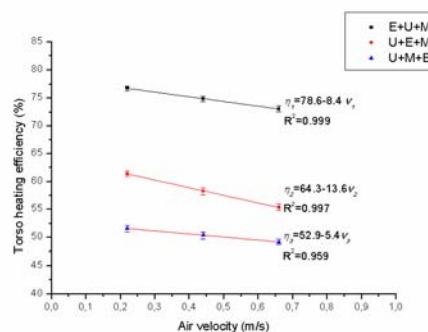
$$\eta = \frac{\Delta HL_{area}}{P_{supply}} = \frac{\sum_{i=1}^n H_i A_i}{P_{supply}}$$

- $\Delta HL_{area}$  is the decrease in the area-weighted heat loss (Watts) from the thermal manikin when the power supply is switched on, compared with when it is switched off. As explained above, the heat loss from the manikin is measured as the power that must be used to maintain the manikin's constant temperature.  $H_i$  is the decrease in the amount of heat from the segment,  $i$  ( $W/m^2$ );  $A_i$  is the surface area of the segment ( $m^2$ );  $P_{supply}$  is the output power of a battery or an external power supply box (W).

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## Results-study 1



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## Results-study 1

- The maximum theoretical heating efficiencies of the EHV in clothing combinations E+U+M, U+E+M and U+M+E (assuming the air velocity is 0 m/s) were 78.6, 64.3 and 52.9 %, respectively.
- The observed temperature on the heating element surface was 40.2 °C, which indicated it is safe for the wearers.

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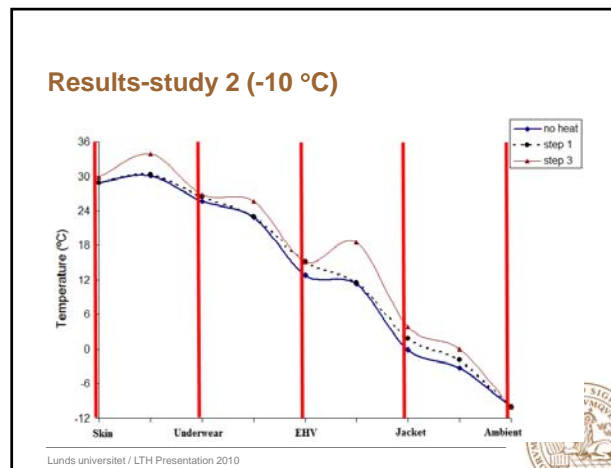
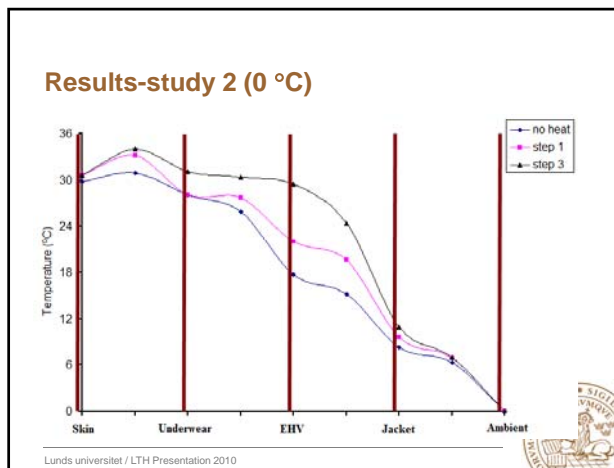


## Results-study 1

- The  $IREQ_{neutral}$  index was used to determine the suitable occupational groups for wearing such an EHV in a three-layer clothing ensemble at 4.5 °C.
- For a person in clothing ensemble U+M+E at 0.66 m/s ( $IREQ_{neutral} = 1.71$  clo), the required metabolic energy production to keep thermal neutral was 108 W/m<sup>2</sup>, i.e., 1.9 Mets.
- For people whose metabolic production is above 1.9 Mets at 4.5 °C, the body can produce enough heat to keep the heat balance. Hence, it is not necessary to use such an EHV.

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## Results

- The EHV can change the evenness of the 'microclimate temperature' distribution of the whole clothing.
- At 0 °C, the heating power at 5 watts is enough to keep the wearer's torso in thermal neutral.
- However, such a heating power for the EHV at -10 °C has almost no contribution.
- The heating power of the EHV should be set in step 3 at -10 °C to generate sufficient heat for the wearer to approach a better thermal condition.

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## Part II

# Air Kinetic vest

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## Kinetic vest



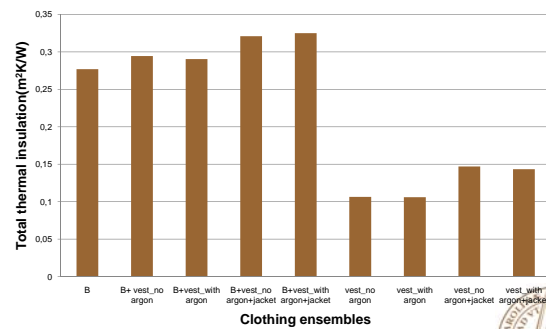
No argon



Filled with argon

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## Results



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## Conclusions

- The **air temperature, air velocity** and **clothing combination** have significant effects on the heating efficiency of the heated vest.
- The EHV alters the temp. distribution inside clothing ensembles.

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## Conclusions

- In order to enhance the heating efficiency of the heated vest, it should be worn as a **middle layer** inside a 3-layer clothing ensemble.
- The air kinetic vest has **no significant contribution** to the clothing thermal insulation compared with the vest without filling the argon air.

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