Finnish Institute of Occupational Health

Cooling strategies for reducing heat strain associated with protective clothing during a fuel cell replacement

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Introduction

Replacement of a fighter aircraft's fuel cell

- physically demanding work
- use of impermeable protective clothing and respirator due to adverse health effects of kerosene
- static postures
- small space
- high intensity work

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→ expose the mechanics to heat strain conditions

- heat strain might be reduced by the use of different cooling systems
- reduction in kerosene exposure?

Aims

- to reduce heat and physiological strain by the means of different cooling strategies,
- to compare cooling strategies and,
- in addition, to reduce kerosene exposure.

Material and methods

Subjects

- Six volunteer male aircraft mechanics

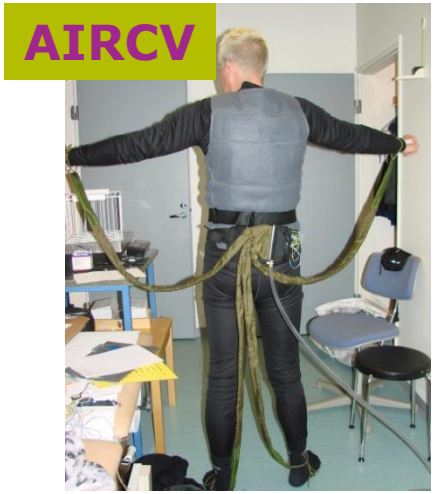
Fuel cell replacement simulation

- in a climatic chamber at ambient temperature of 25 °C
- volume of the cell: 1 m^3
- size of the container: 131 x 120 x 92 cm (HxLxW)
- work was to pack the fuel cell ready for removal trough an opening (30x40 cm)
- duration 50 – 60 min

Cooling systems

Three cooling systems used

1) cooling vest with 22 PCM elements (CV), weight 2230 g
2) air cooling (AIR), weight 900 g, air flow 700 l/min
3) combined air cooling and cooling vest (AIRCV)
4) no cooling was used as a control (NO).



Clothing

- long sleeved and legged underwear
- impermeable protective coverall (Tychem® F2, DuPont™)
- pneumatic respirator
- protective gloves and socks

Measurements

- core (thermopill) and skin temperatures
- heart rate
- sweat rate
- thermal sensation
- rate for perceived exertion (RPE)

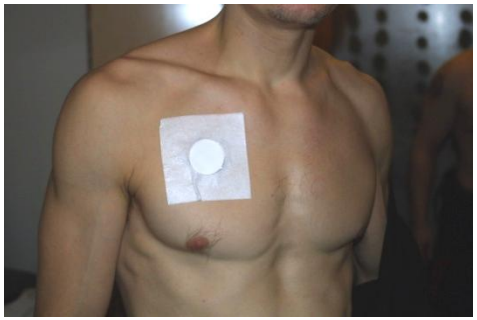
Chemical exposure assessment during a real fuel cell replacement

Air concentration of kerosene

- with diffusion badge from breathing zone

Dermal exposure to naphthalene

- surface of the skin (back and chest)

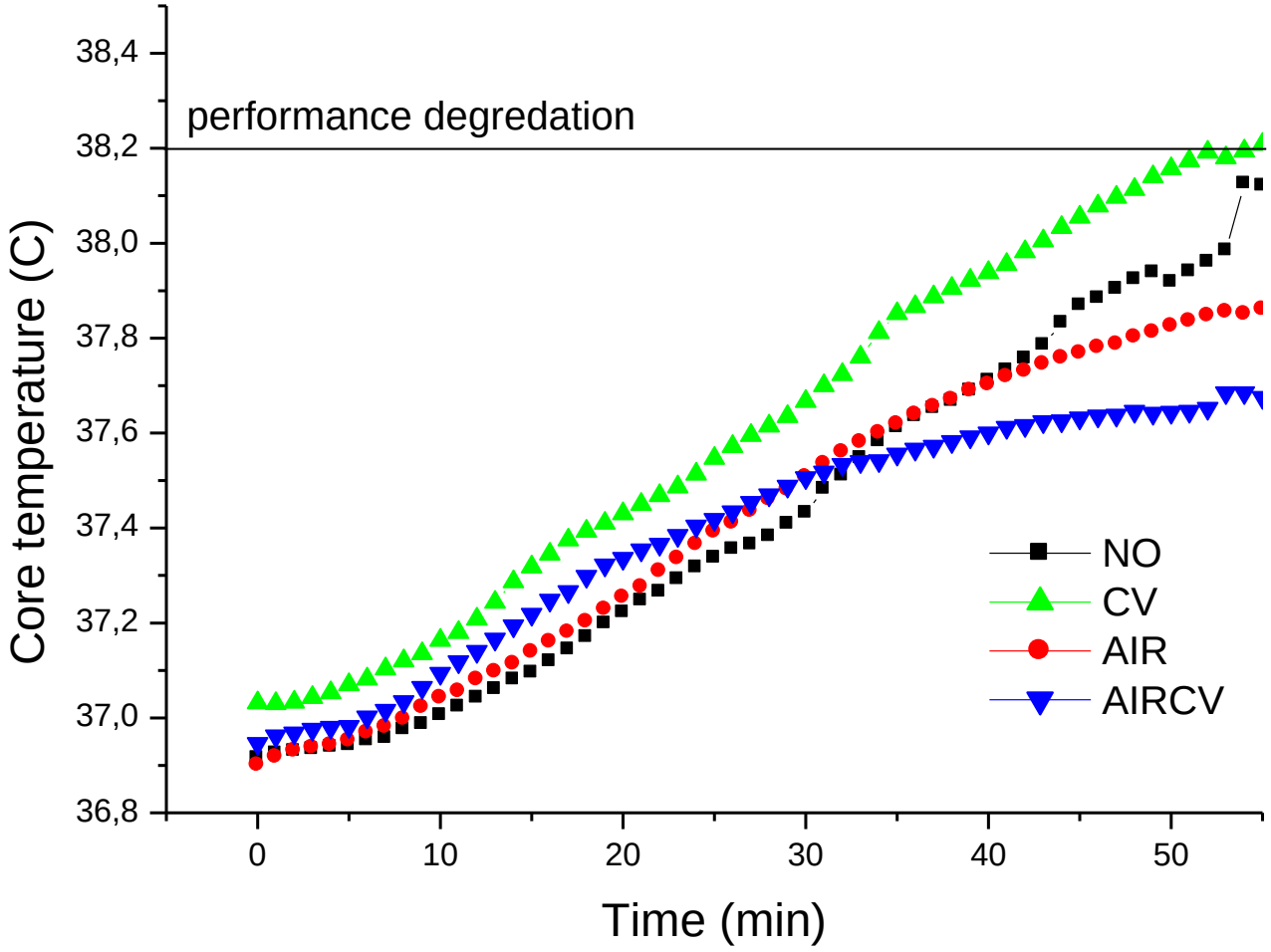


Total exposure to kerosene

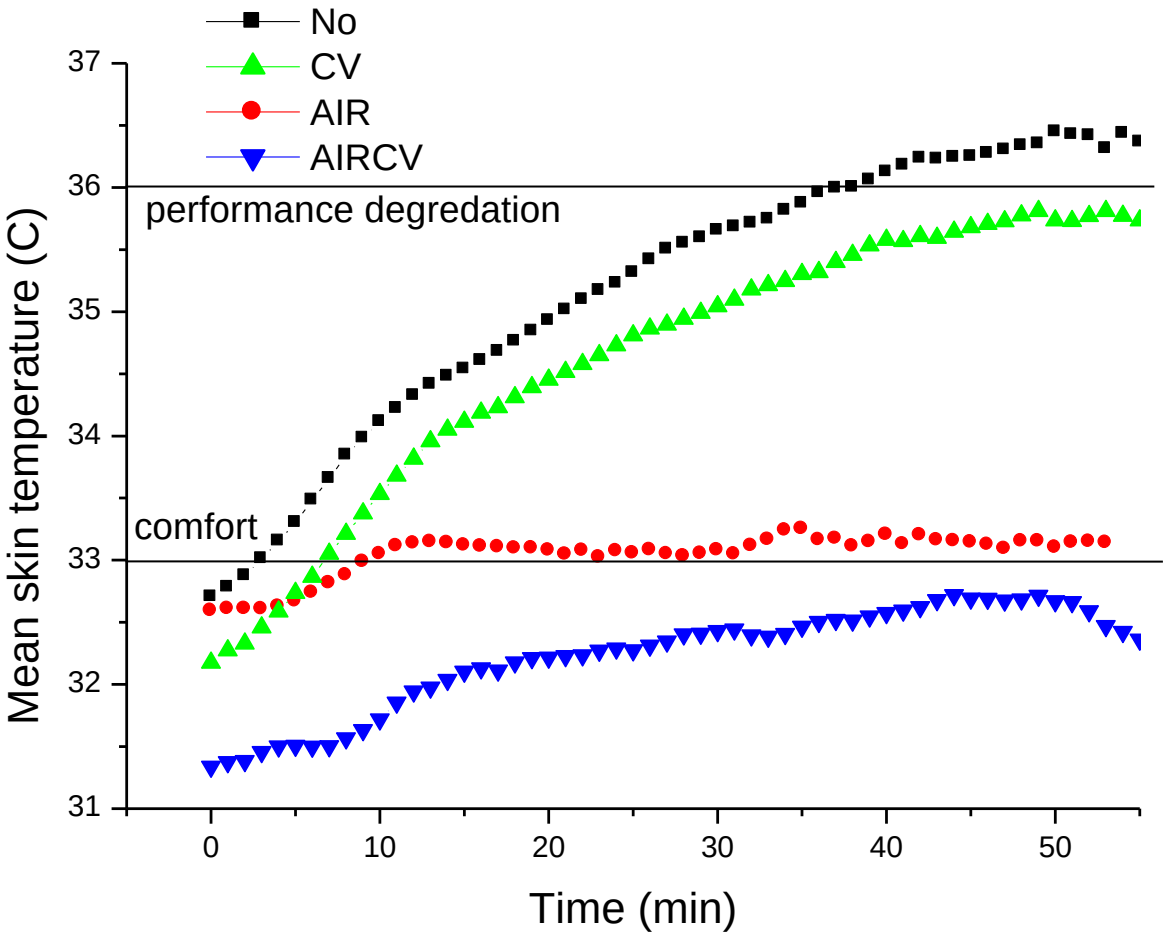
- urinary 1-naphthol excretion before exposure, immediately after, 6 hours after the end and next morning

Air cooling system

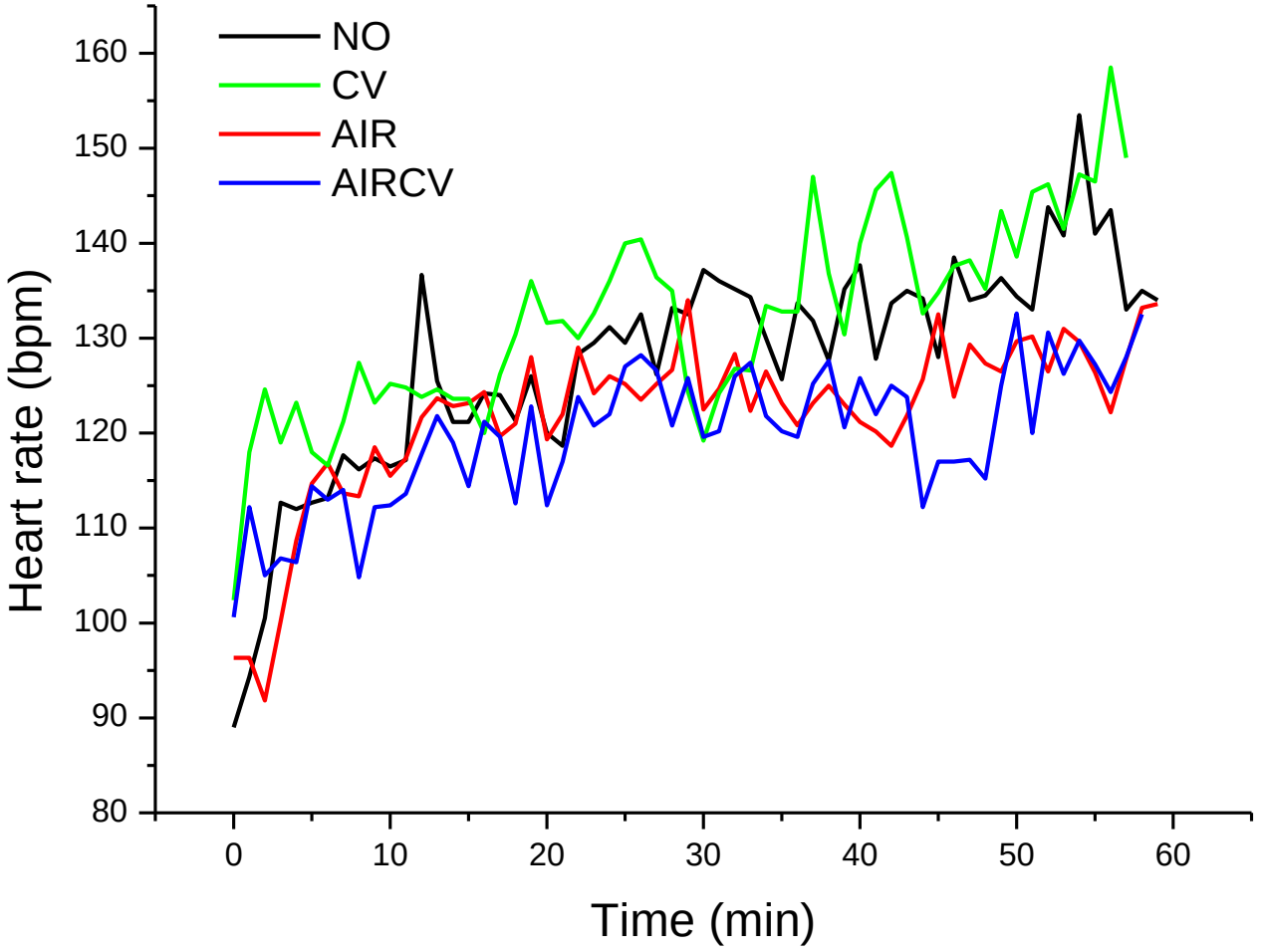
Results - core temperature



Results – mean skin temperature



Results – heart rate



Results - thermal sensation and RPE

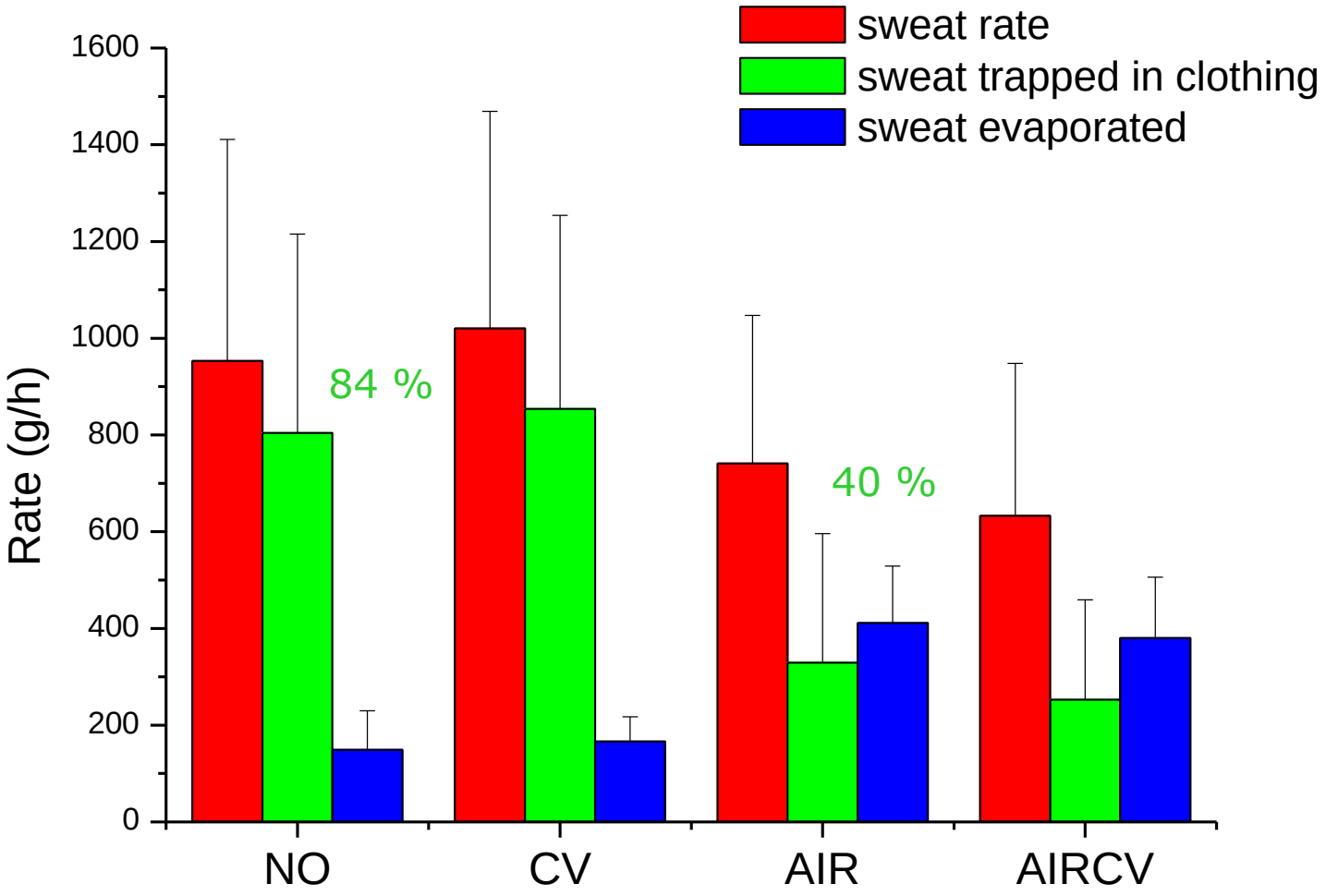
Thermal sensation

- NO: 3 hot
- CV: 2,5 hot
- AIR: 2 warm
- AIRCV: 1,5 warm

Rating of Perceived Exertion

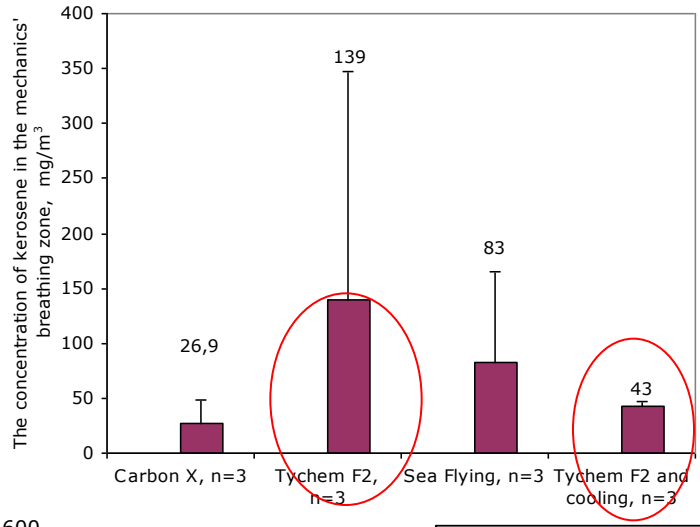
- AIR and AIRCV: hard
- CV and NO: extremely hard

Results - sweating

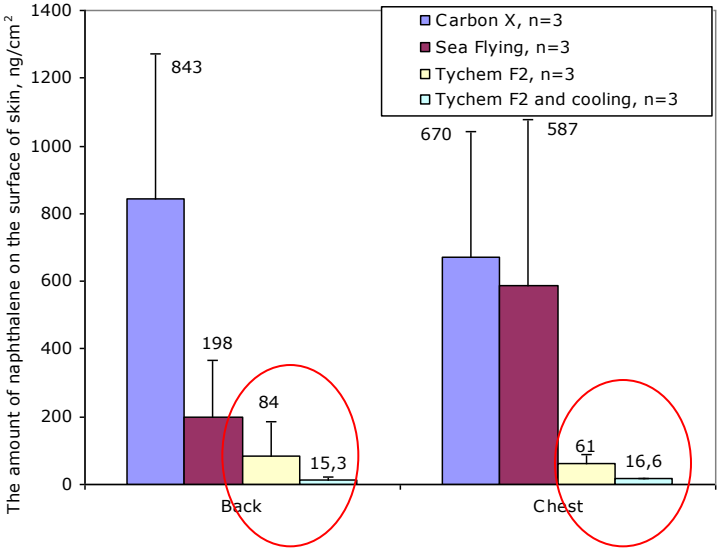


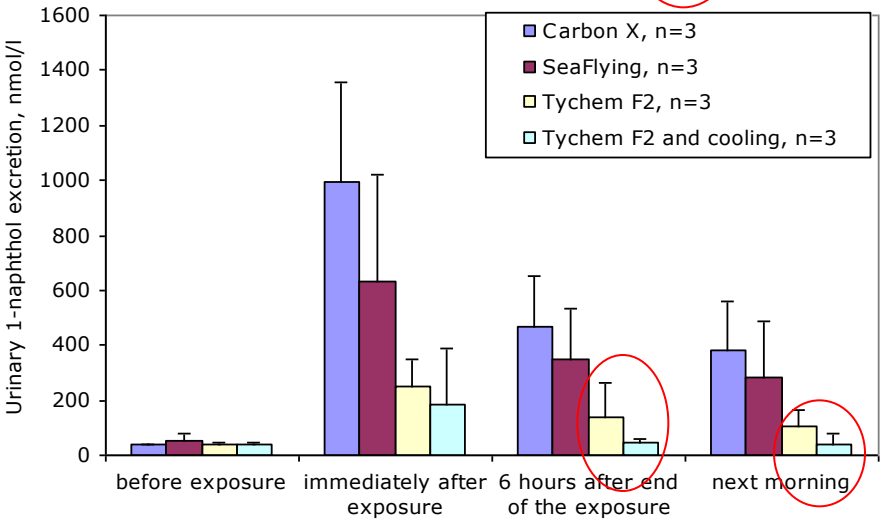
Results - exposure to kerosene

Concentration of kerosene in breathing zone



Amount of naphthalene on skin surface





Urinary 1-naphthol excretion

Air cooling (AIR) reduced exposure to kerosene compared to without cooling.

Conclusions

Cooling vest (CV)

- not effective alone
- reduced sweat evaporation

Air cooling or combined air and cooling vest systems

- reduced significantly heat and physiological strain of the mechanics during the fuel cell replacement simulation
- enhanced sweat evaporation resulting in dryer underwear and thus more pleasant microclimate inside the protective clothing
- reduced fatigue and enhanced faster recovery

Conclusions

Air cooling in the field reduced

- exposure to kerosene
  - concentration of kerosene in breathing zone was lower
  - amount of naphthalene on the skin surface was lower
  - urinary 1-naphthol excretion was lower

It's highly recommended that personal protective equipment are used during fuel cell replacement together with **air cooling** or combined air and cooling vest devices.

Questions?