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Finnish Institute of
Occupational Health



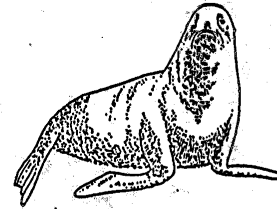
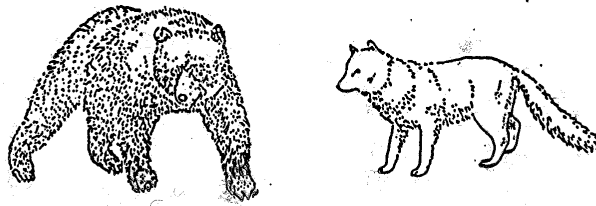
Human physiological and behavioral responses to cold

Hannu Rintamäki

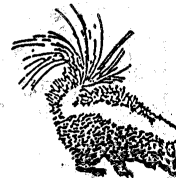
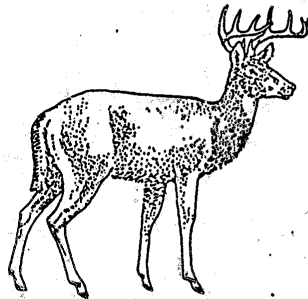
Physical Work Capacity team, Finnish Institute of Occupational Health

University of Oulu, Institute of Biomedicine, Department of Physiology

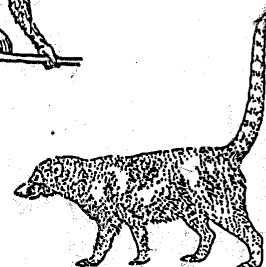
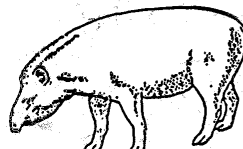
Arctic zone



Temperate zone



Tropical zone



- warm or hot days
- cooler nights

Requirements for thermal comfort

- Body is in heat balance
- Core temperature is $36.5 - 37.1^{\circ} \text{ C}$
- Mean skin temperature is $32.5 - 35^{\circ} \text{ C}$
- Difference in local skin temperatures is less than 5° C
- Regulation of heat loss only by the adjustment of skin and peripheral circulation
 - no sweating
 - no shivering

How to get a **feeling** of thermal comfort?

Keep warm

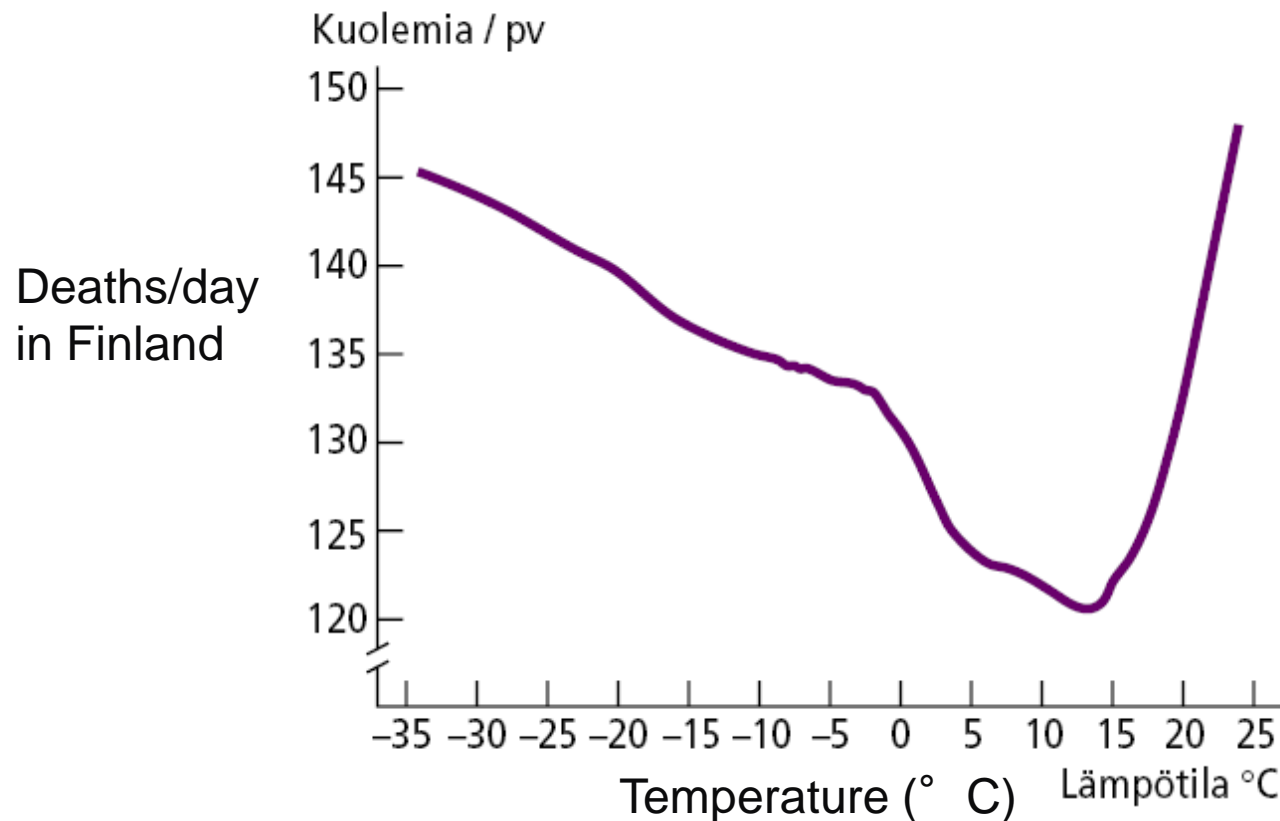
- torso (especially abdomen)
- neck

Thermal limits of humans



- 33° C Thermal comfort in water
- 27° C Thermal comfort in air
- 24° C Safest temperature for Mediterranean population
- 14° C Safest temperature for Finnish population
- 10° C Upper limit for cold work
- 1° C One hour without hypothermia
(when naked and at rest)

Mortality is affected by ambient temperature



KUVA 2. Kokonaiskuolleisuus ja päivän keskilämpötila (Joki-oinen) Suomessa vuosina 1961–1997. Tasoitetut luvut (lowess-menetelmä). Aineistot: Tilastokeskus ja Ilmatieteen laitos.

Näyhä 2005



***Physical
work***

Metabolic
heat
production

***Human
heat
balance***

Environment

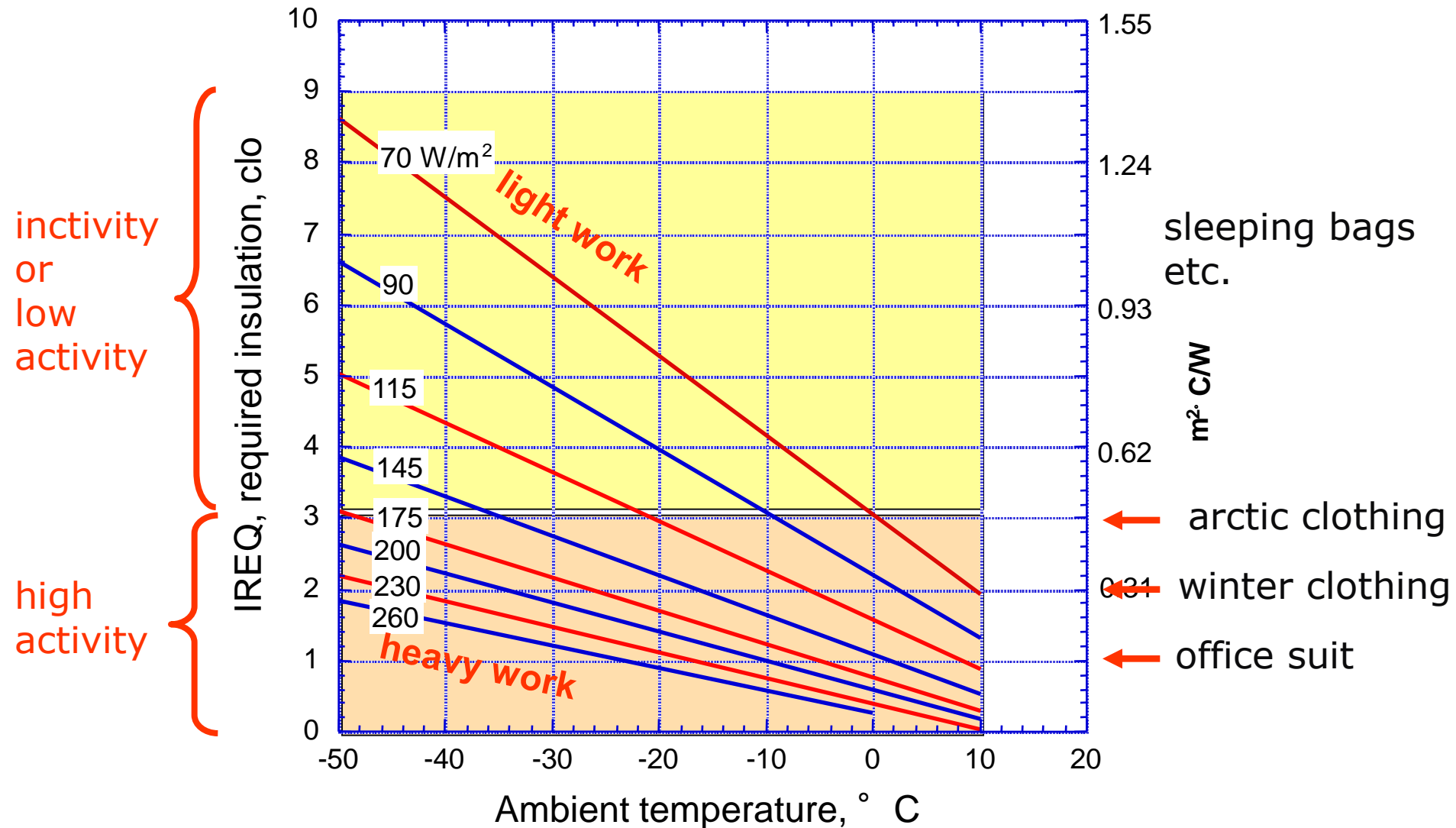
Thermal stress:
- low temperature
- wind

Clothing

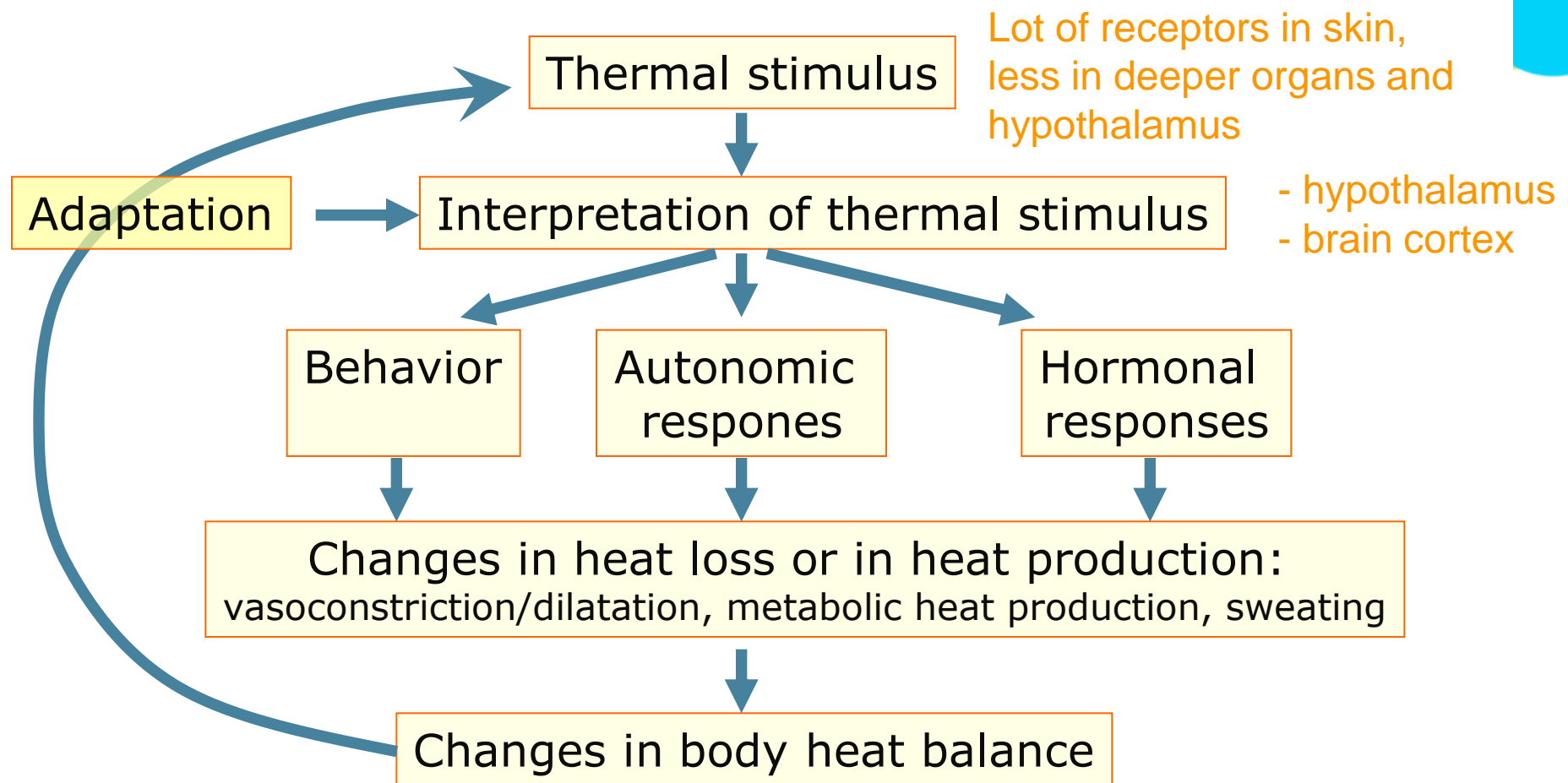
Thermal insulation

Required thermal insulation of clothing

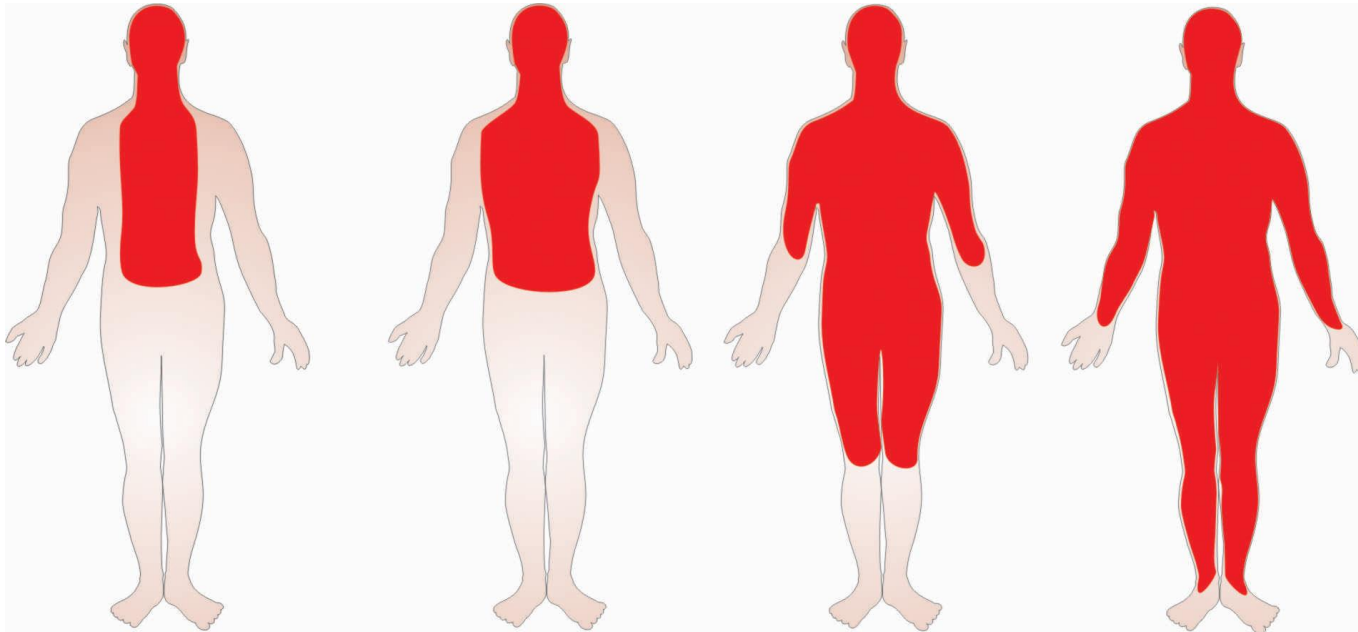
ISO 11079, Holmér 1988



Basic thermoregulatory responses



Core and shell temperatures



Hypothermia

Normal

Hyperthermia

Core temperature is regulated to maintain homeostasis and performance

Shell (skin and extremities) temperature is regulated to adjust heat loss

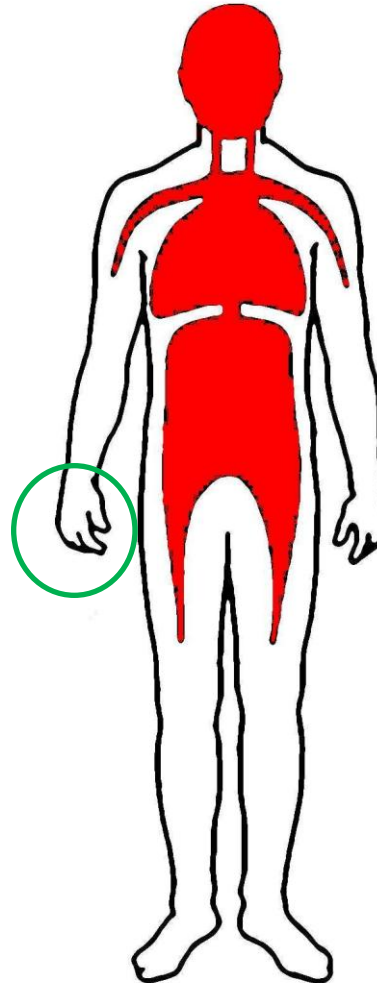


Circulation

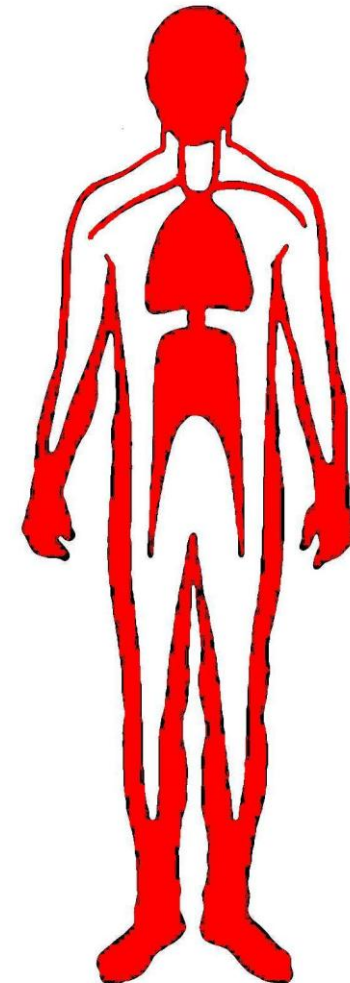
In cold:

- Constriction in small arteries and veins in skin and limbs
 - not in head
- **Increases blood pressure by 20–60 mmHg**
- Increase in work load of heart

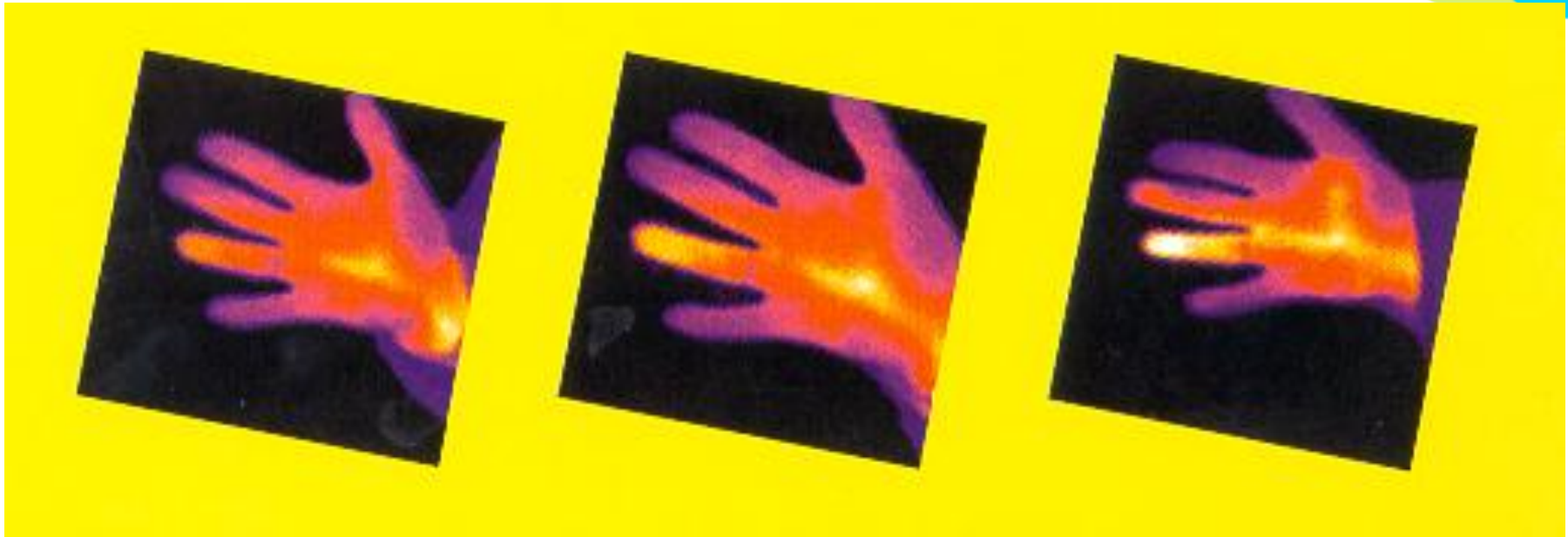
in cold



in warm



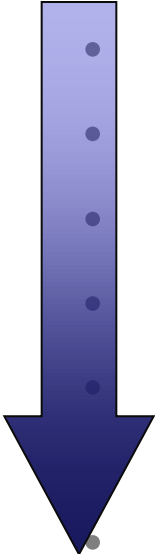
Cold Induced Vasodilatation (CIVD)



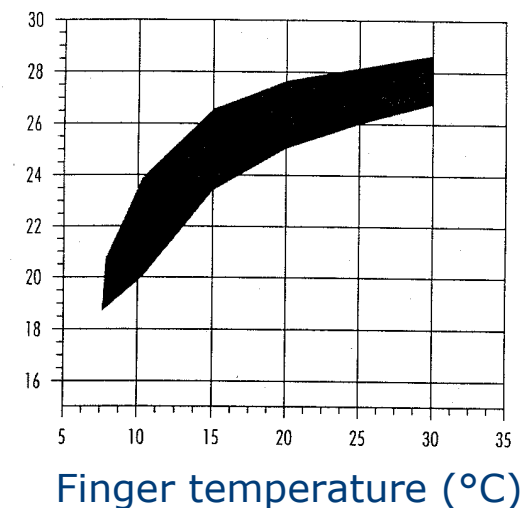
CIVD: opening of anastomoses between small arteries and veins

CIVD is facilitated by cold adaptation

Negative effects of cold

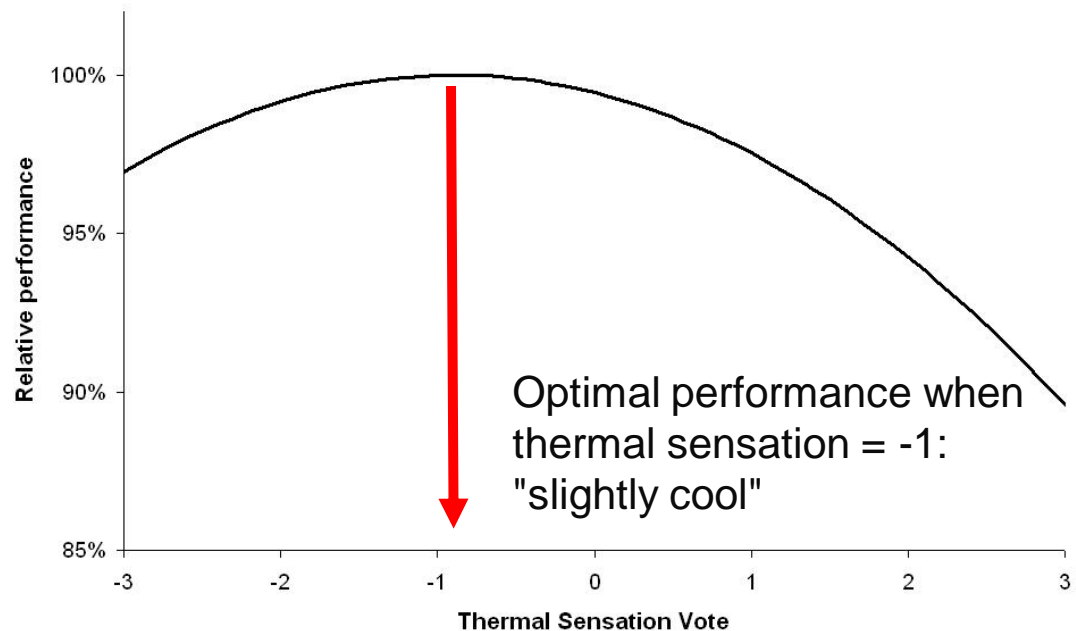
- 
- Discomfort
 - Performance decrement
 - Pain (skin temperature ca. 15° C)
 - Numbness (skin temperature below 7° C)
 - Frostbite (sharp increase below air temperature of -22° C)
 - Hypothermia
-
- Increased morbidity and mortality in risk groups
 - old people
 - people with cardiovascular or respiratory diseases

Manual dexterity



Benefits of cold

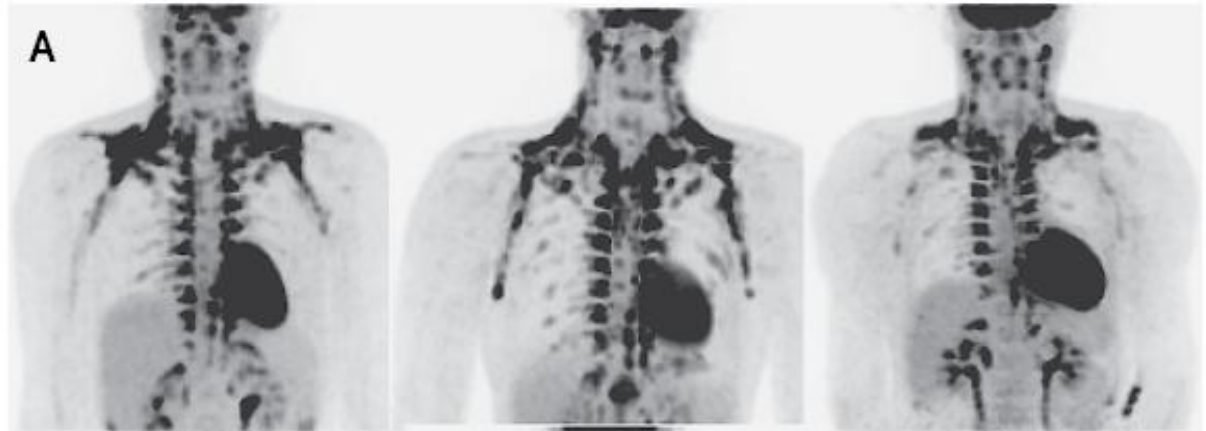
- Heavy work is possible without heat stress
- Increased arousal
 - mental performance is best when thermal sensation is "slightly cool"



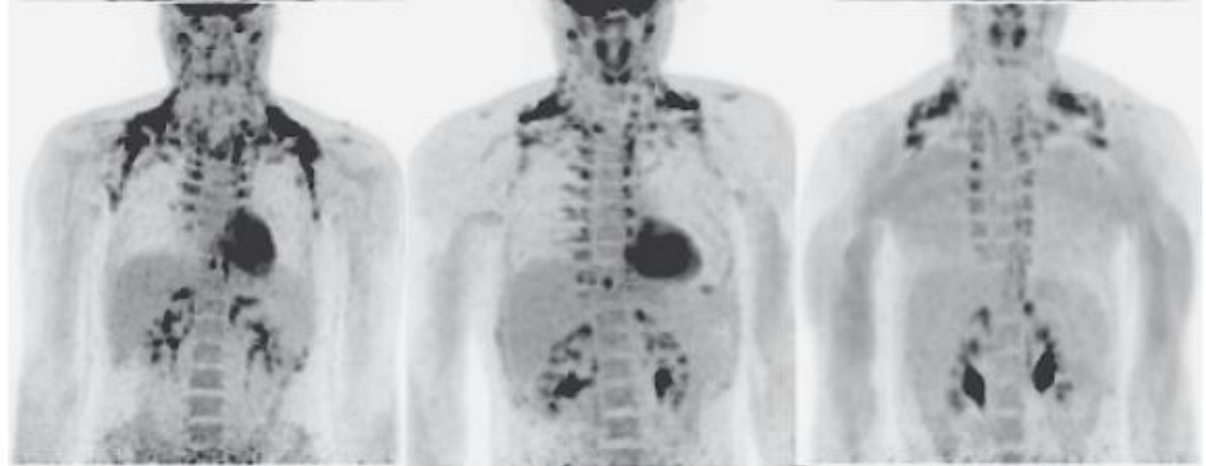
**There is
brown
adipose
tissue also
in adult
humans**

**Activity
found in
PET-CT-
scanning**

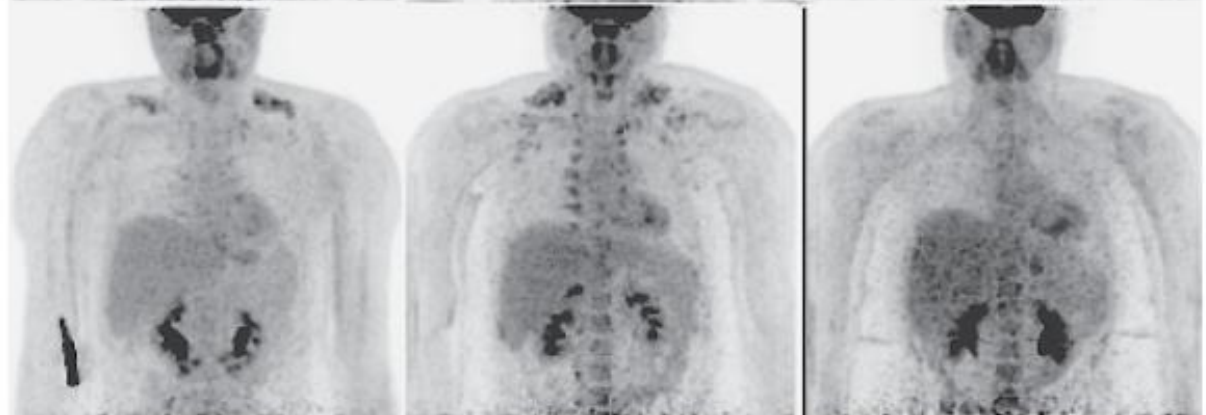
lean



lean



obese

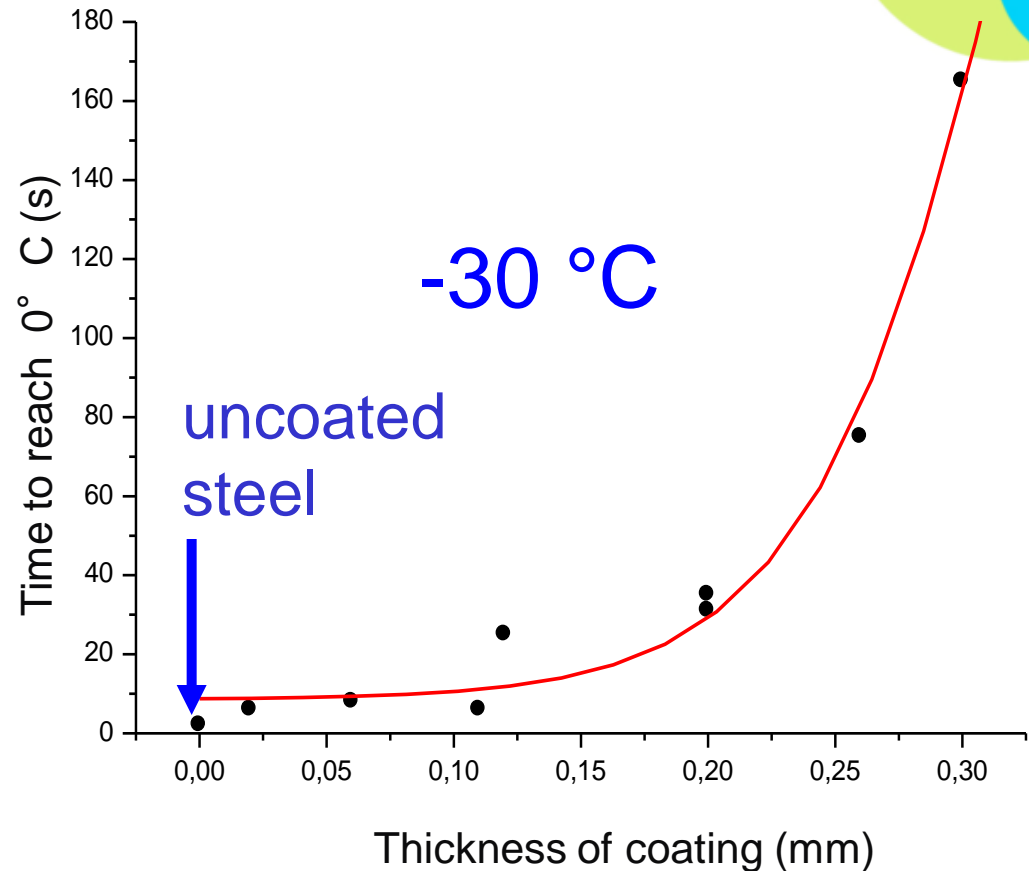
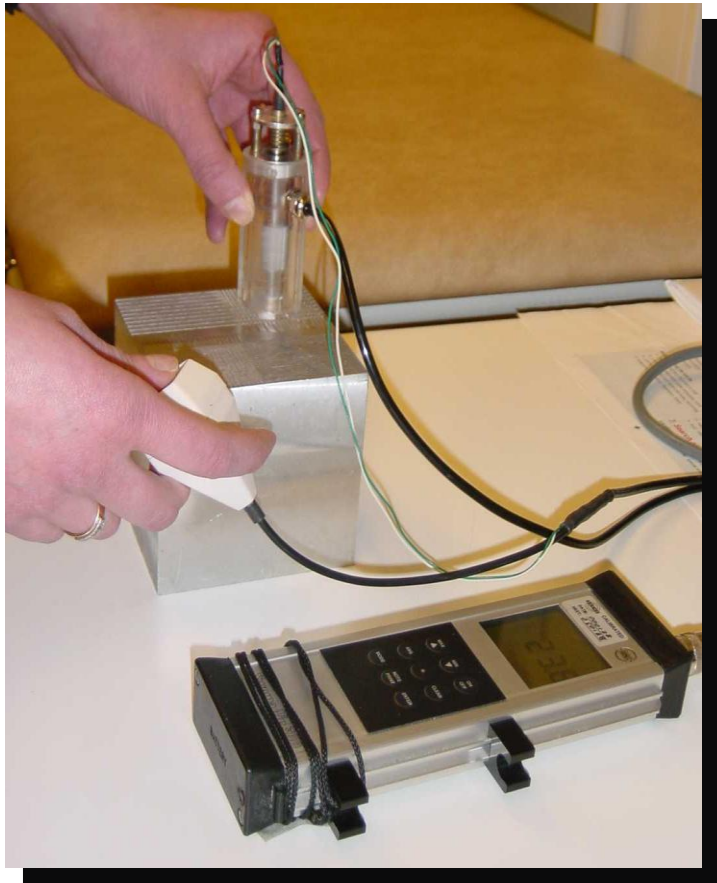


Effect of clothing on energy costs and performance

- Increased energy costs are due to
 - weight
 - bulkiness
 - friction
- Weight of clothing increases energy cost by **ca. 3 %/additional kg**
 - x 1.2 for the head
 - x 1.9 for the hands
 - x 4 - 6 for the feet
- Increased energy costs \approx decrease in physical performance
 - task specific



Even a 0.3 mm coating prevents contact cooling



measurement by artificial fingertip



Don't do this

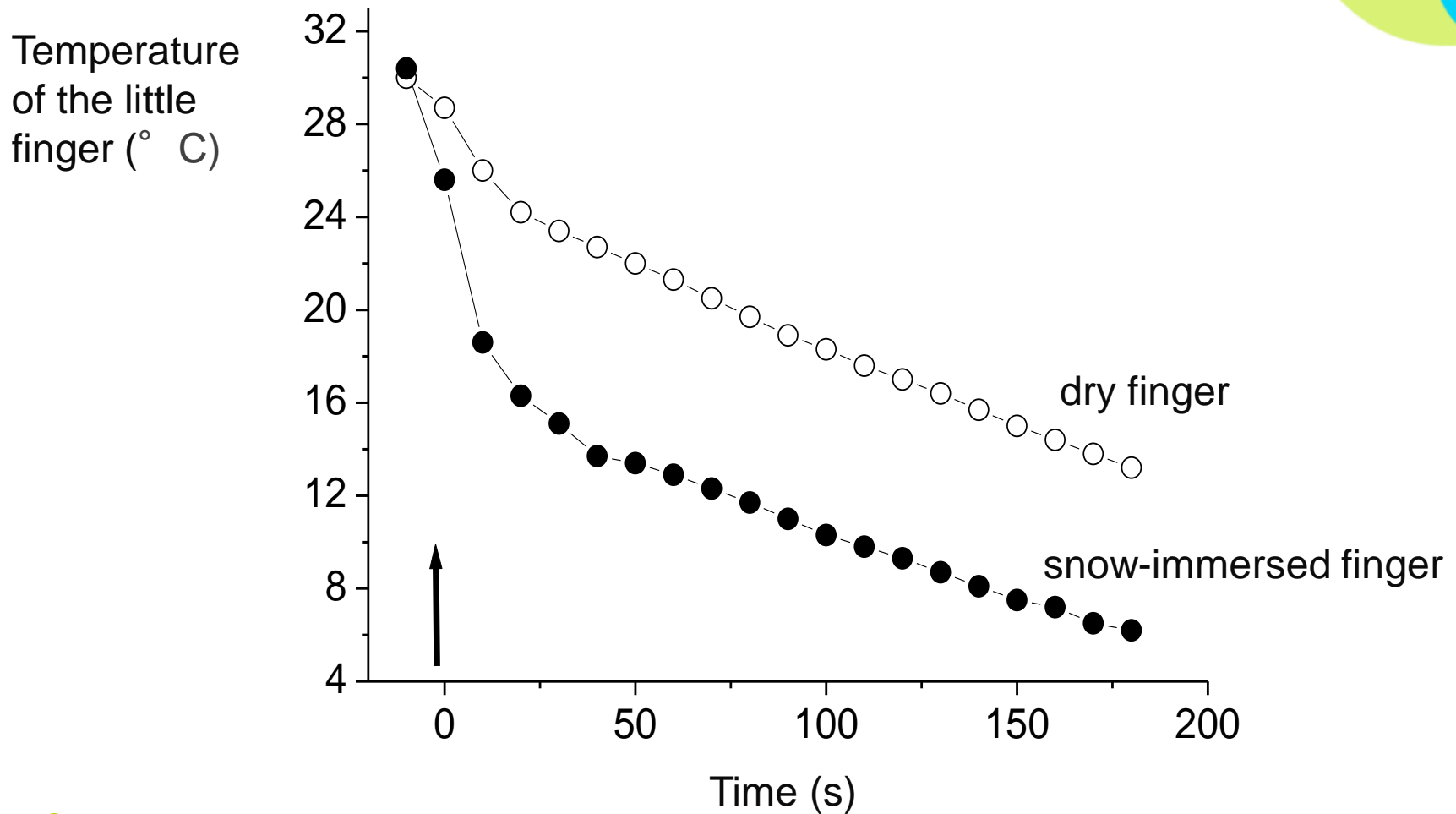


-10°C, wind 2 m/s

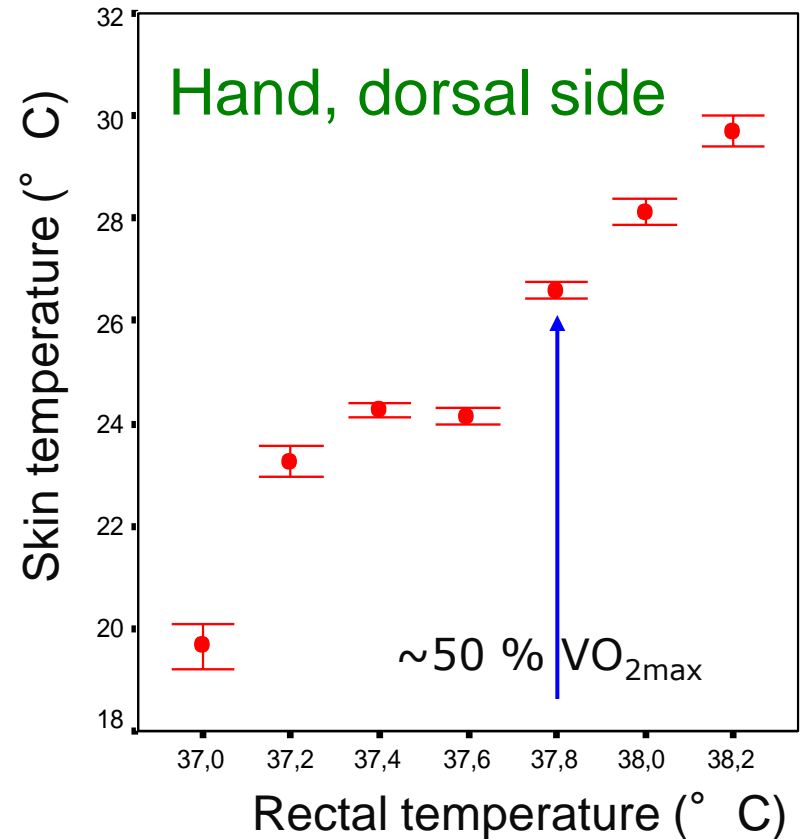
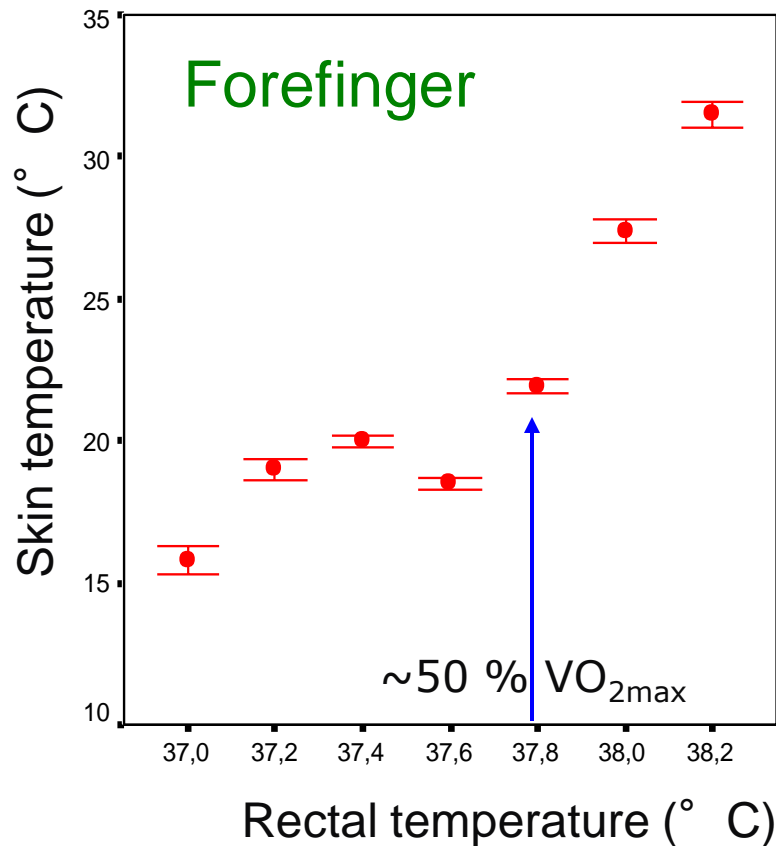
-10°C, wind 2 m/s



Single snow immersion cools finger by 8° C



Do this: Moderate exercise opens circulation in hands and feet



Cold/dry air may cause constriction of upper airways



Cold air is always dry

Air temperature (°C)	Water (g) in a m ³ of air (relative humidity is 100 %)
30	30.4
20	17.3
10	9.4
0	4.8
-10	2.4
-20	1.1
-30	0.4

Heavy work cools airways

Increased ventilation

→ strong cooling and drying

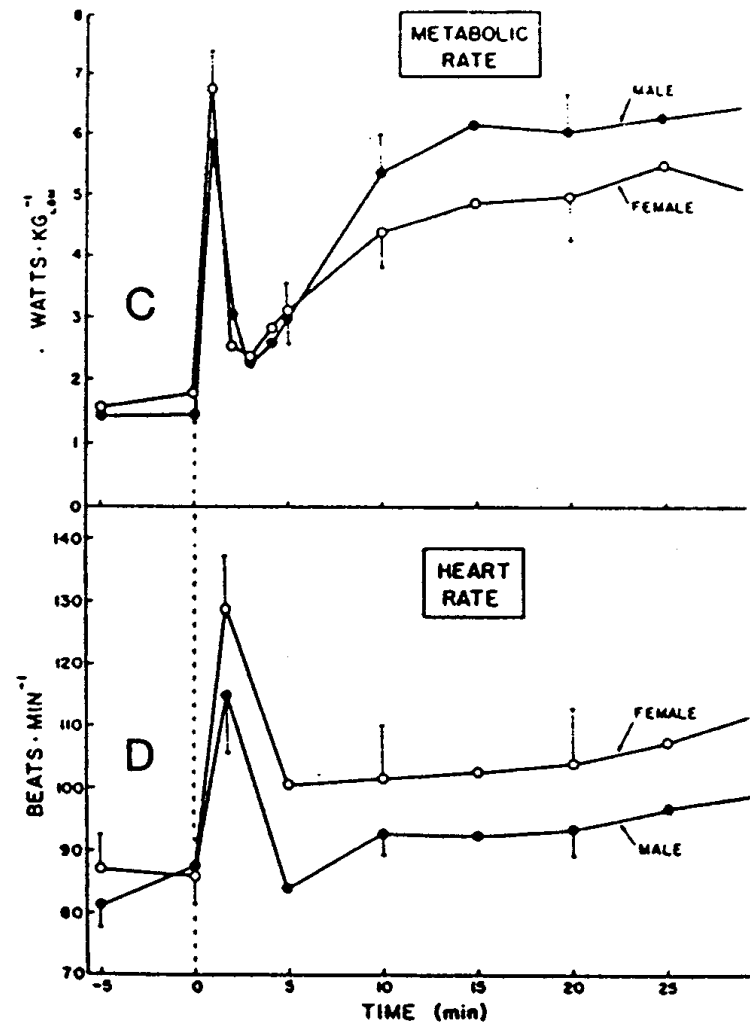
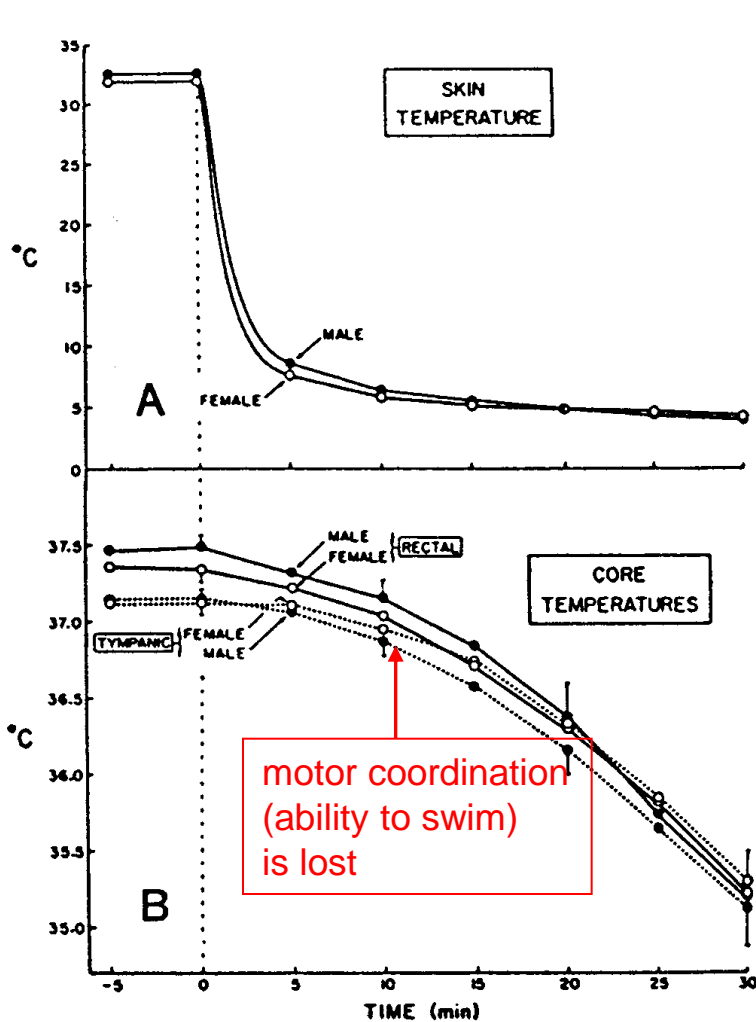
→ strong constriction of upper airways

→ wheezing of breathing

Good experiences from moisture and heat exchangers



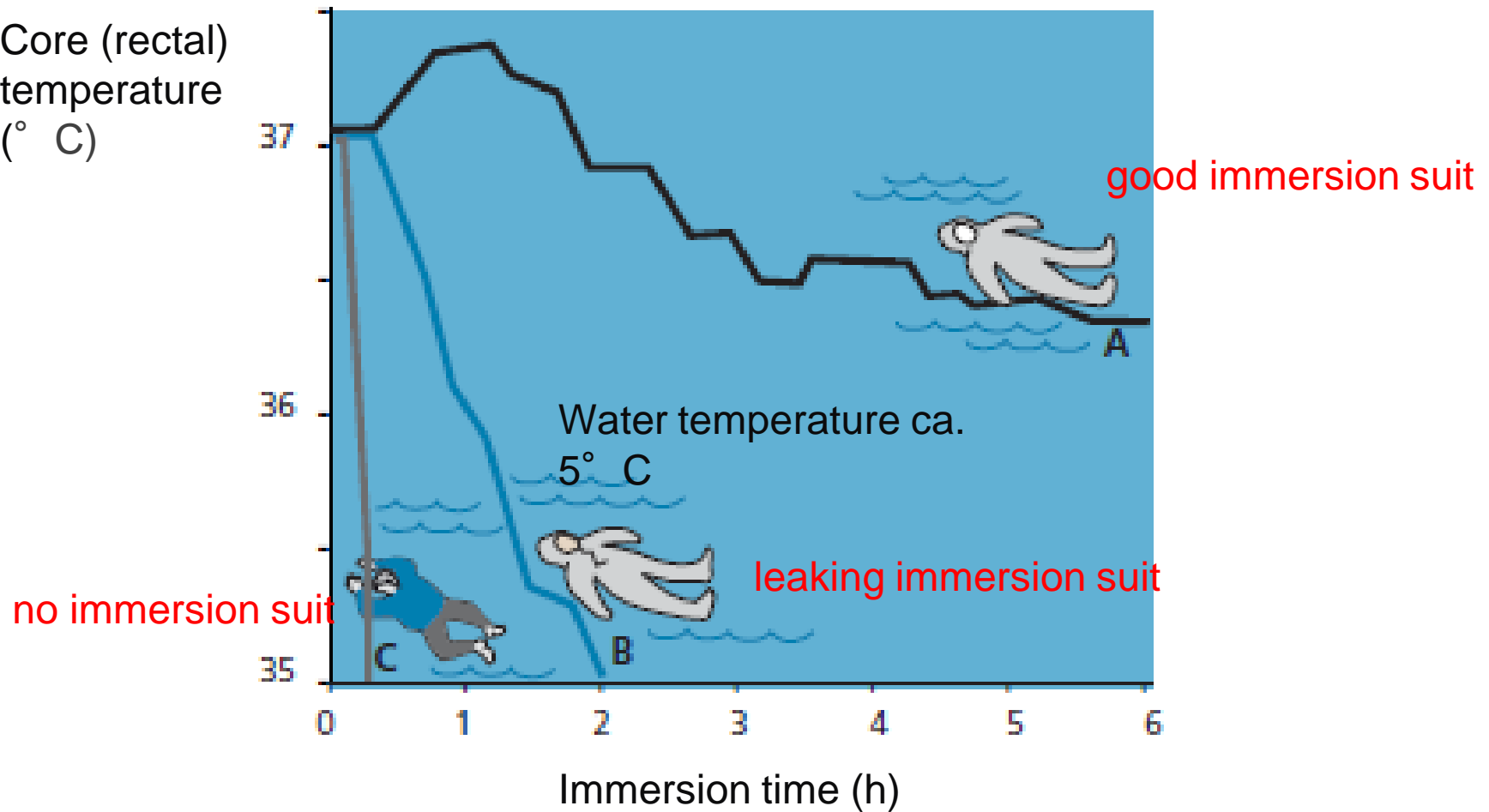
Responses to cold water



Hayward & Eckerson 1984

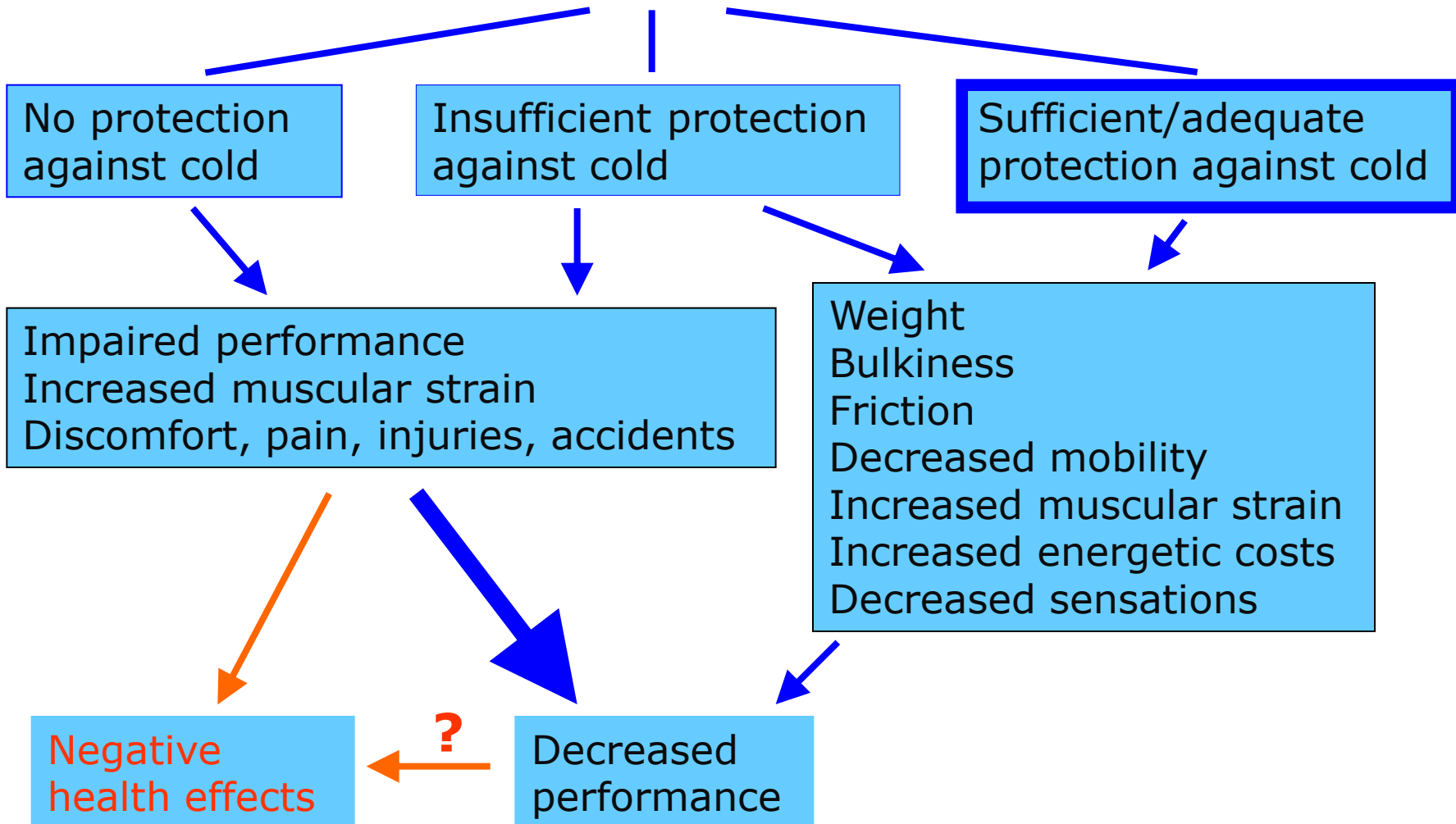


Core (rectal)
temperature
(° C)



Conclusions

MAN IN THE COLD



More information (in Finnish)/



Ilmarinen Raija, Lindholm Harri, Läärä Jukka, Peltonen Oula-Matti, Rintamäki Hannu ja Tammela Erja:
Hypotermia - Kylmän haitat työssä ja vapaa-aikana. Työterveyslaitos 2011

<https://verkkokauppa.ttl.fi/>