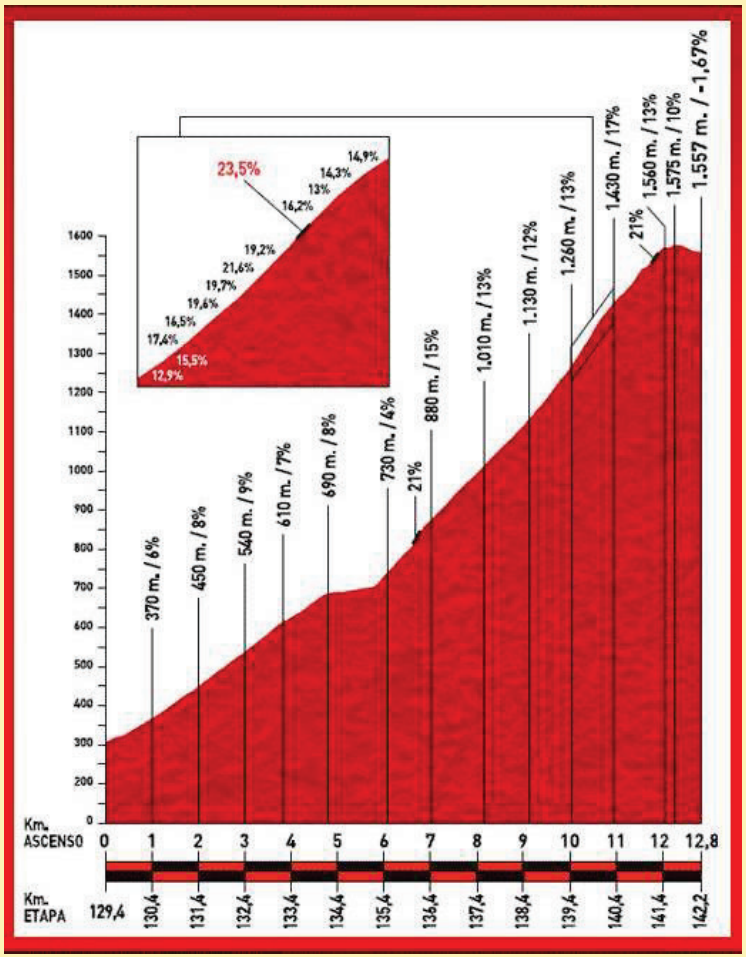
Computer Modelling of Energy Turnover and Body Temperatures in Elite Cyclists during Climbing

Cold, colder, Gavia

Source: www.pezcyclingnews Andy Hampsten's Epic Stage

Source: KillingMonteZoncolan.blogspot.nl



Steep, steeper, Angliru

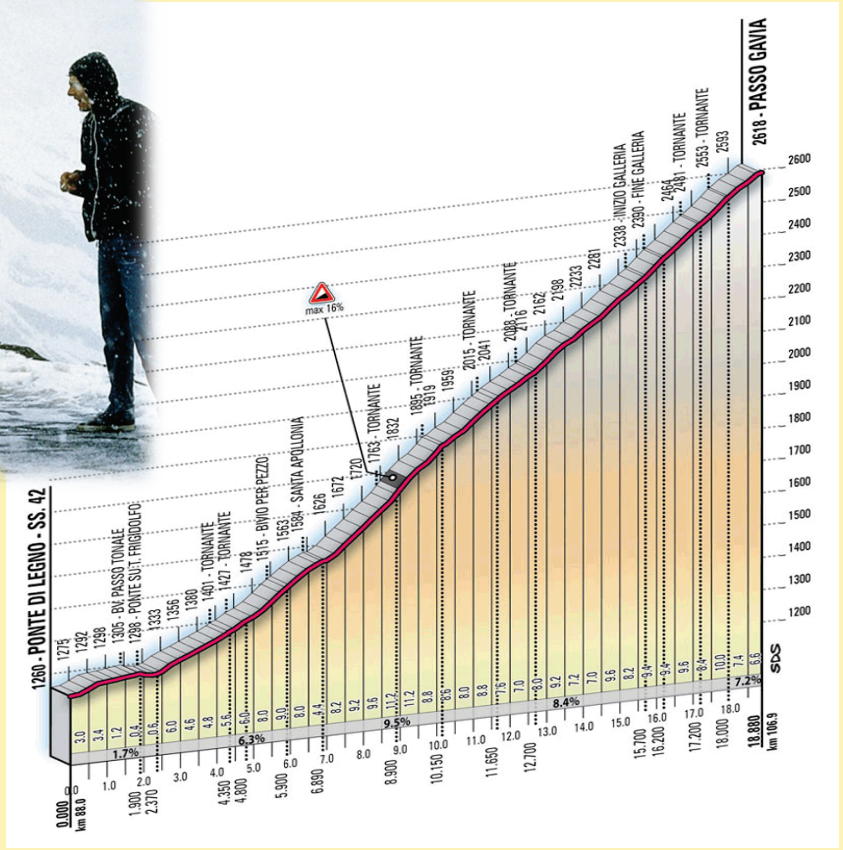
Hans van Beek & Marjolein Verhoeven

VU medisch centrum

History of Cycle Racing

“Epic days: the Passo di Gavia, Giro d’Italia 1988”

Source: www.pezcyclingnews Andy Hampsten’s Epic Stage



EL PASSO DI GAVIA EN EL GIRO 1988, LA ETAPA MÁS DURA DE LA HISTORIA DEL CICLISMO MODERNO

Source: A-discrecion.blogspot.nl

Trend in Cycle Racing

Including steep climbs

Tre Cime di Lavaredo
Monte Zoncolan
Angliru
Mortirolo etc.

Potential overheating problem

Riders are slower, less cooling by wind

Source: Iconicphotos

WHAT'S THE STEEPEST GRADIENT FOR A ROAD BIKE?

Image: VeloNews.com

WHY WOULD CYCLISTS push a bike? In the case of a recent stage of Tirreno-Adriatic, there were three parts with a 27 percent gradient. Yes. That's pretty steep for a bike.

Source: Wired.com

Discussing the 27% climb in today's stage with @martinvelits & wondered what's the steepest gradient you could possibly ride on a road bike?

— Mark Cavendish (@MarkCavendish) March 11, 2013

Health Hazards

Body and brain temperature getting too high because of high intensity exercise with limited cooling (hyperthermia)

Source: keepcalm-o-matic.co.uk

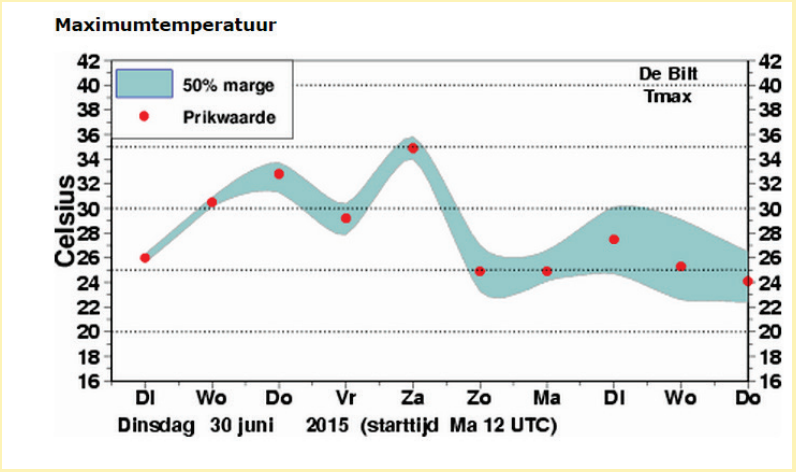
How is this situation affected by the low speed of the cyclist on very steep slopes which reduces wind cooling ?

Body and brain temperature getting too low in cold weather (hypothermia)

Source: ctnews.com

How is this affected by the high intensity of the muscle work ?

Source: KNMI

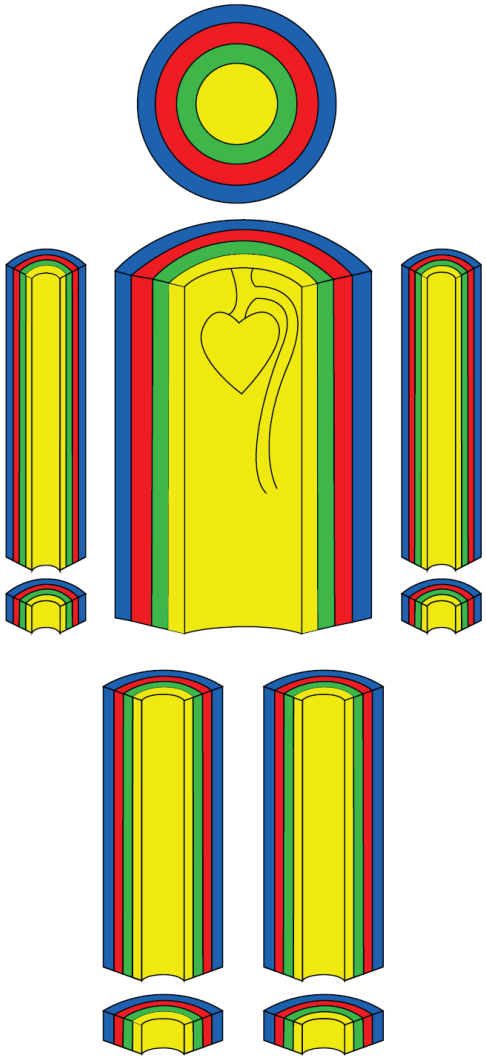


Computer Model Predictions

Our goal is to predict by computer simulation how an intense climbing effort on steep slopes or under cold conditions affects body and brain temperatures

Computational model of energy conversion and heat transport

Where does the energy in a cyclist's body go?



core
muscle
fat
skin

- **More than ¾ of energy is converted to heat**
- heat transport : equations for astronaut by **Jan Stolwijk** (NASA)
- blood transports heat in body
- heat transported by conduction
- sweat evaporation dissipates a lot of heat from body
- air temperature, humidity and wind velocity taken into account

Simulating Time Trial to Alpe d'Huez

- We try to translate athletic top performance in a computational model
- We start with 'normal' temperatures and slopes
- Essential ingredients were available to simulate winner climbing Alpe d'Huez :

winning time 39 min 41 sec in Tour de France 2004

distance 15.5 kilometer

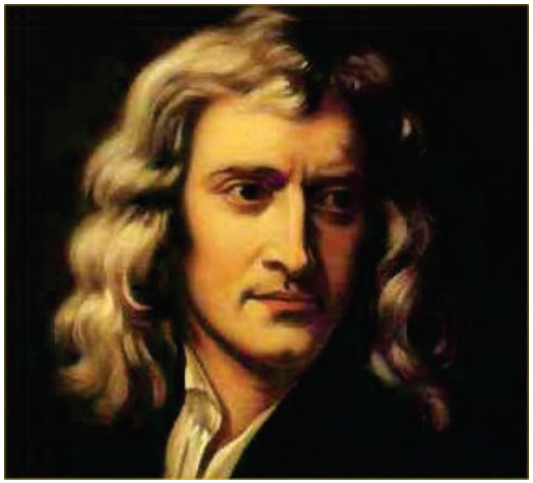
gradient Alpe d'Huez 8-11%

physiological data winner

was followed for years by an exercise physiologist – article in Journal of Applied Physiology

mechanics Isaac Newton, energetics James Watt

etc. etc.



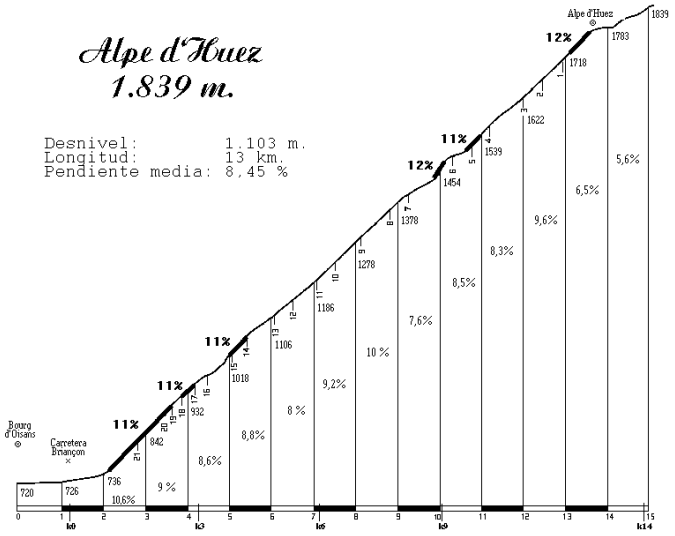
published in: Philosophical Transactions of the Royal Society, 2011

including open source computer code

Where does the energy in the cyclist's body go on Alpe d'Huez ?

Heating the Body

Gravity, rolling resistance, air resistance, acceleration



To realize winning time

(39 min 41 sec)

- 450 Watt mechanical power to cycle
- 1600 Watt heat
- ***very high*** oxygen uptake
  5.9 litres/min

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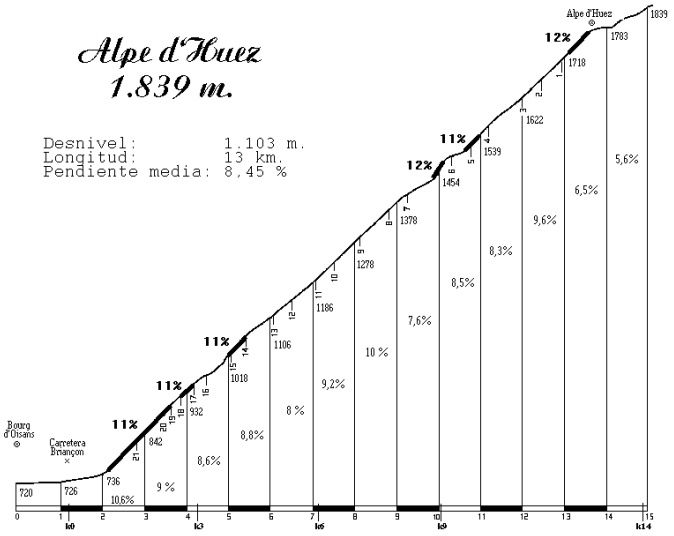

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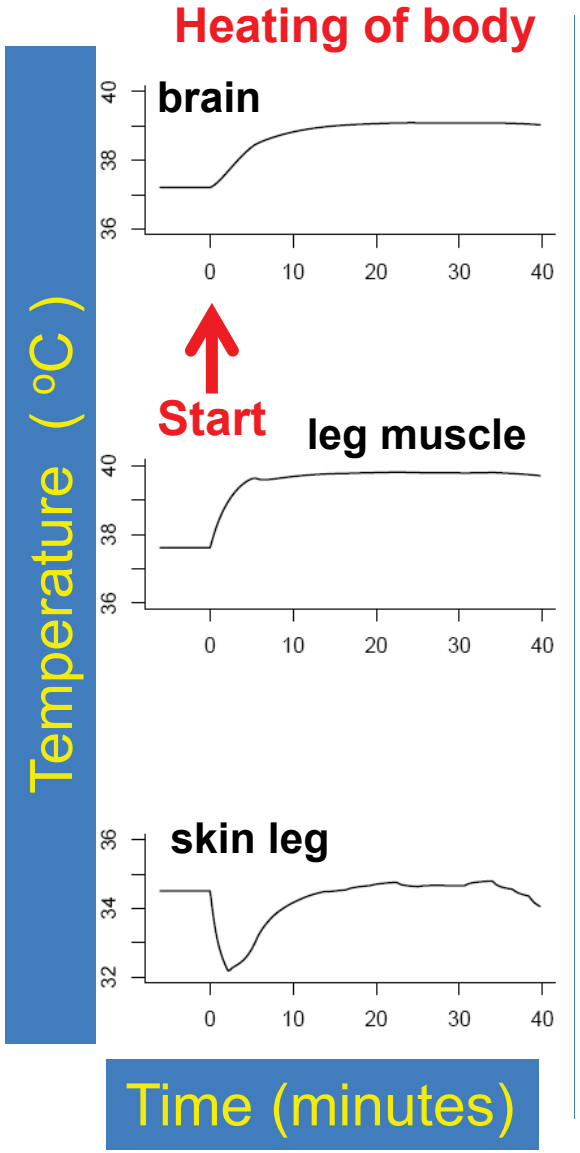

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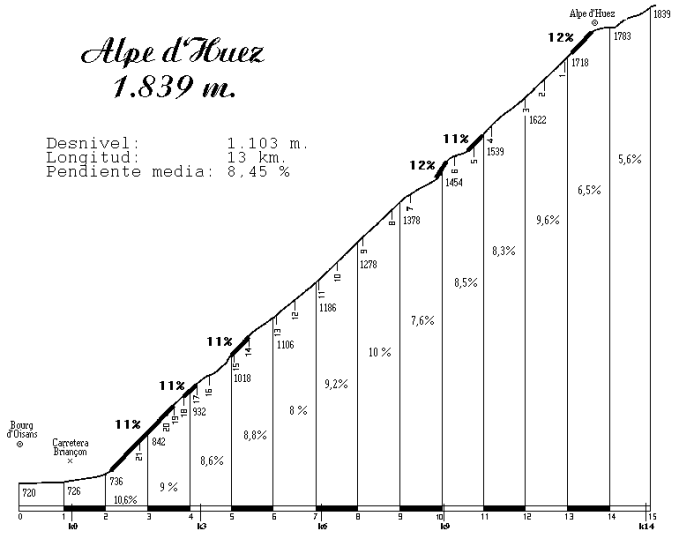

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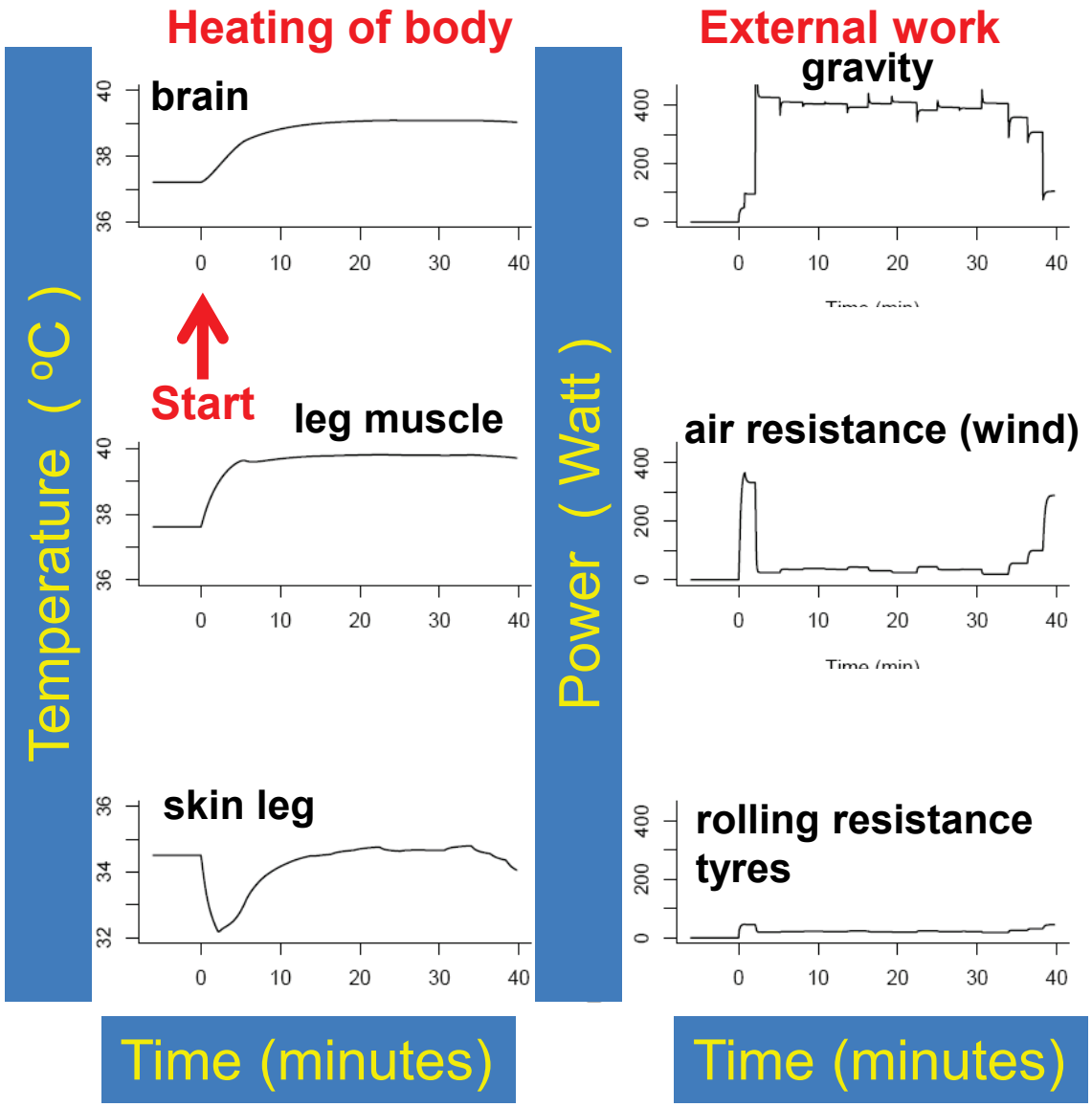
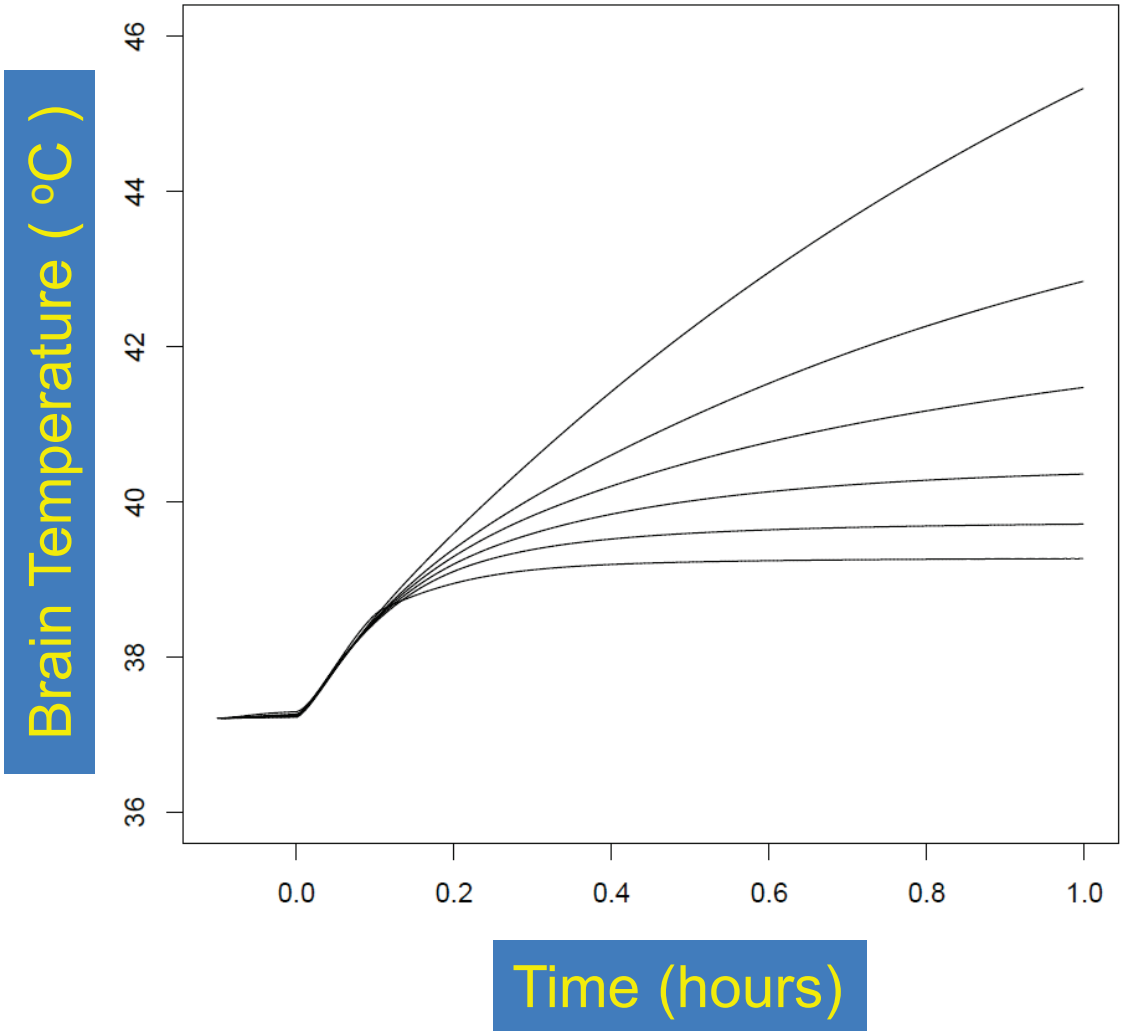


Effect of Wind Cooling – Stationary Bicycle



Wind velocity (meter/sec)

0.1

0.2

0.3

0.5

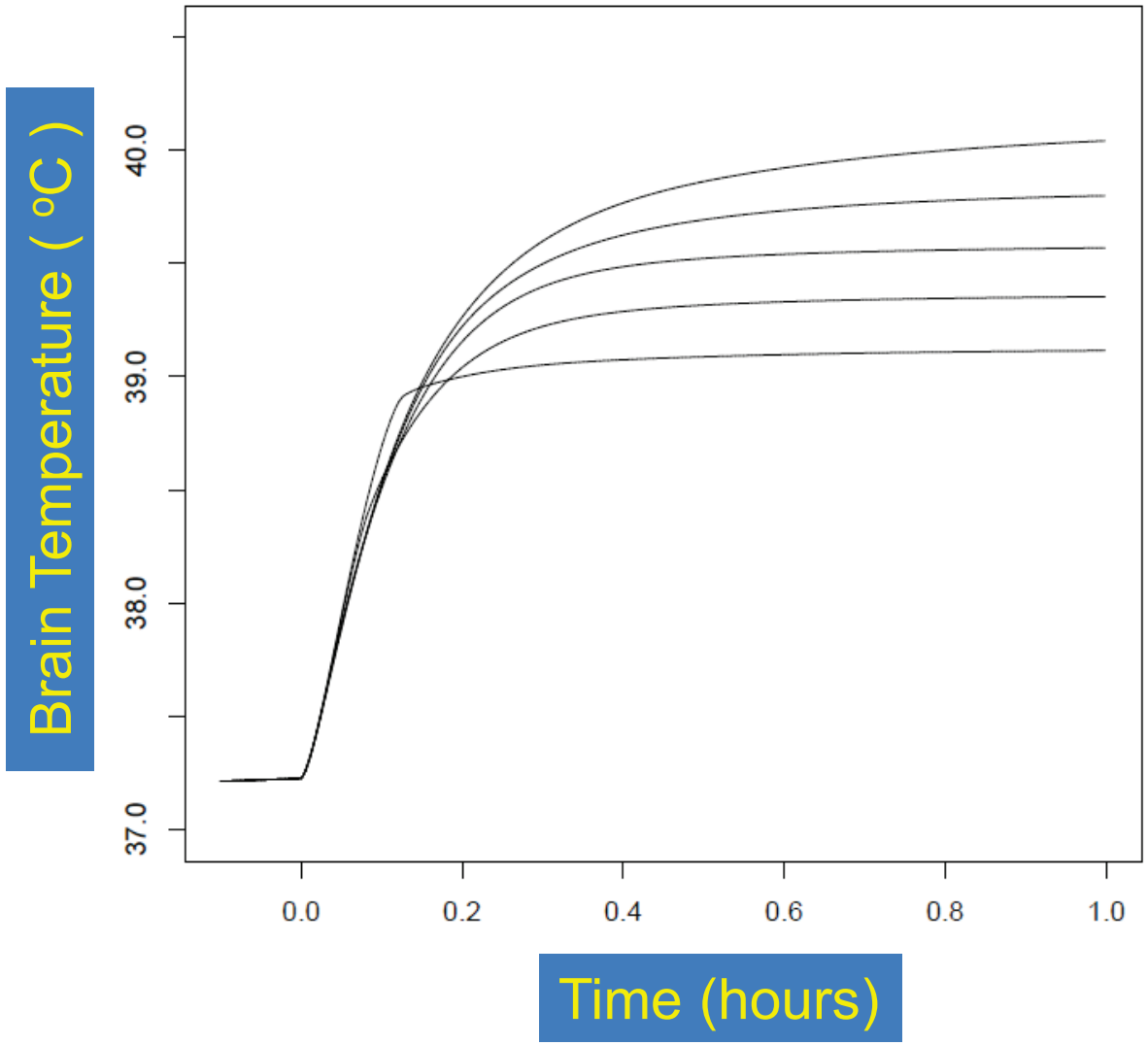
1.0

5.0

Brain:
45 °C and rising !
(without ventilator)

Air temperature:
24 °C

Effect of Steep Slopes

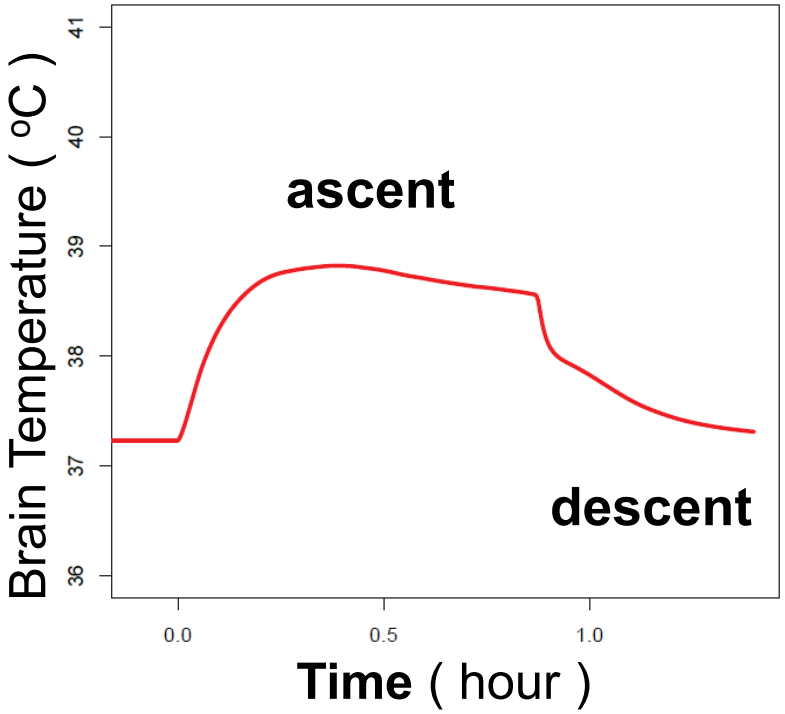


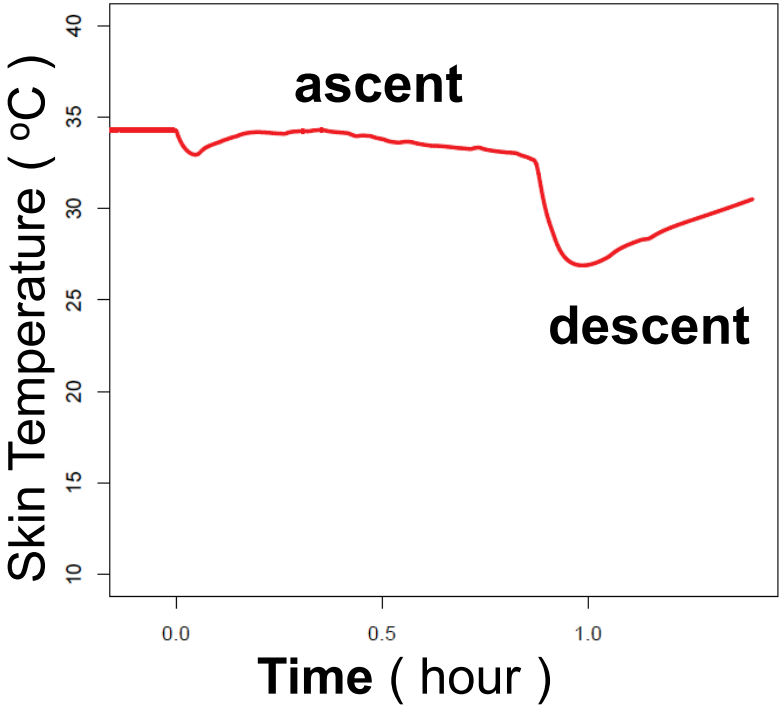
Slope	Speed (km/h)
90%	2.5 hypothetical
60%	3.8
30%	7.5
10%	21
0%	49

0

Climbing the Passo di Gavia

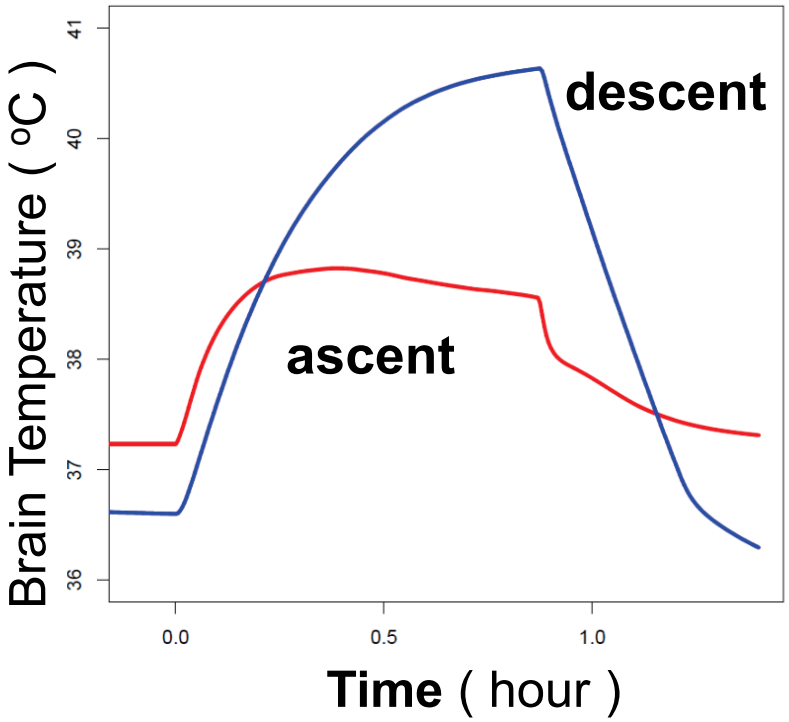
Warm : 18 °C on summit

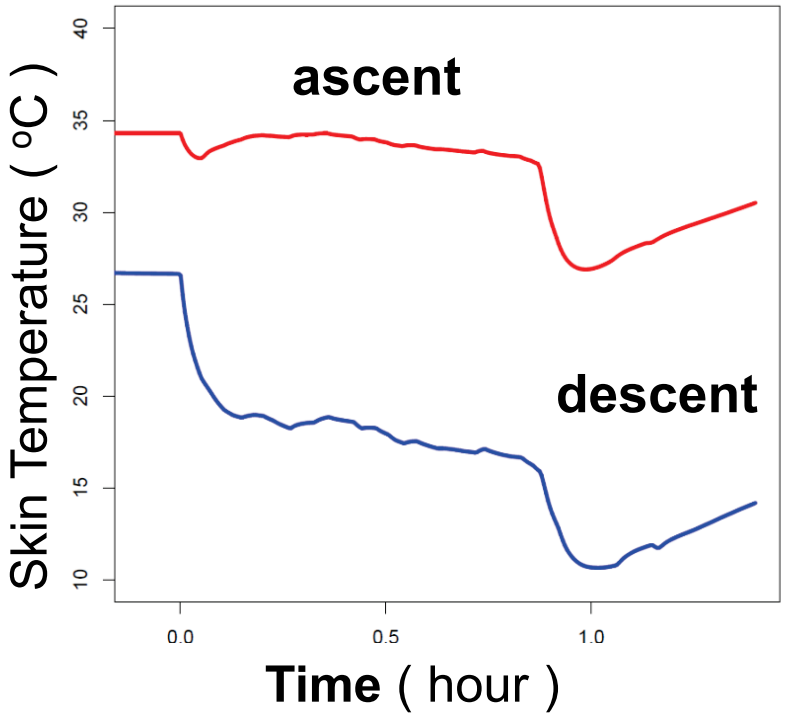




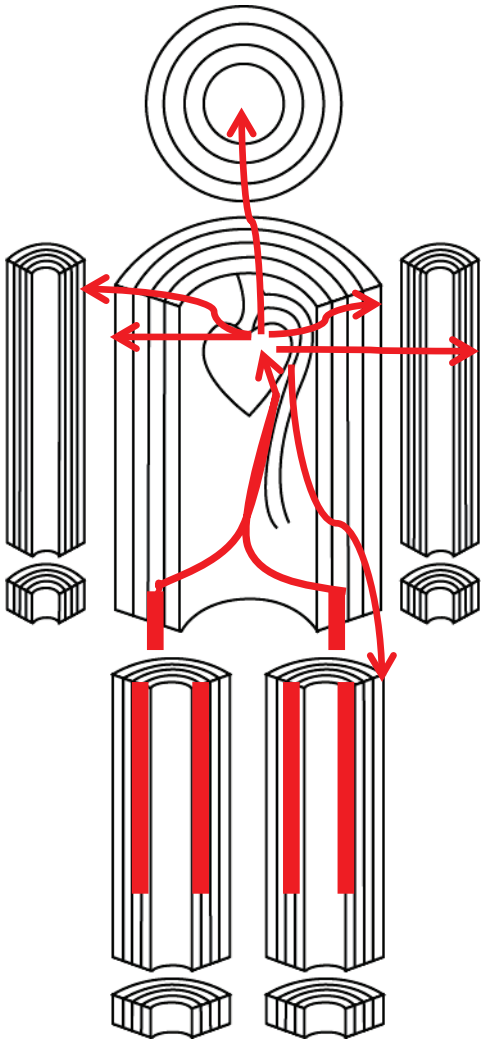
Climbing the Passo di Gavia

Warm 18 °C / Freezing -4 °C on summit

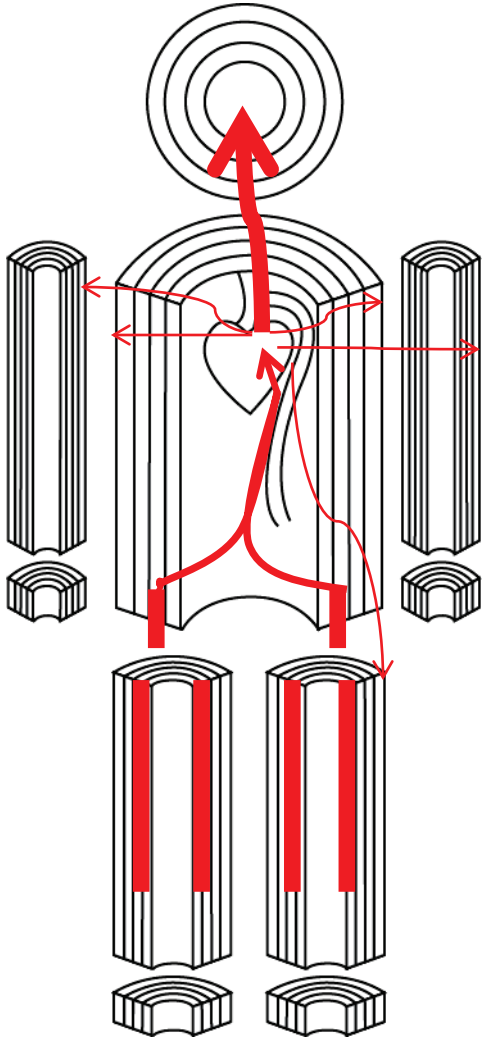




Muscle heat gets trapped in body – causing high brain temperature



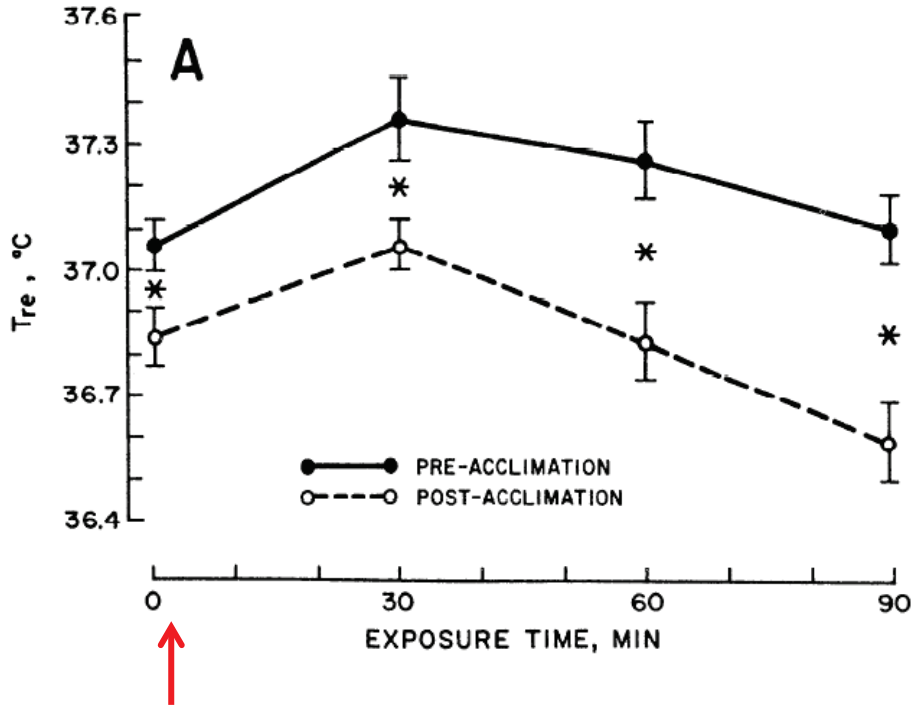
Neutral



Cold conditions

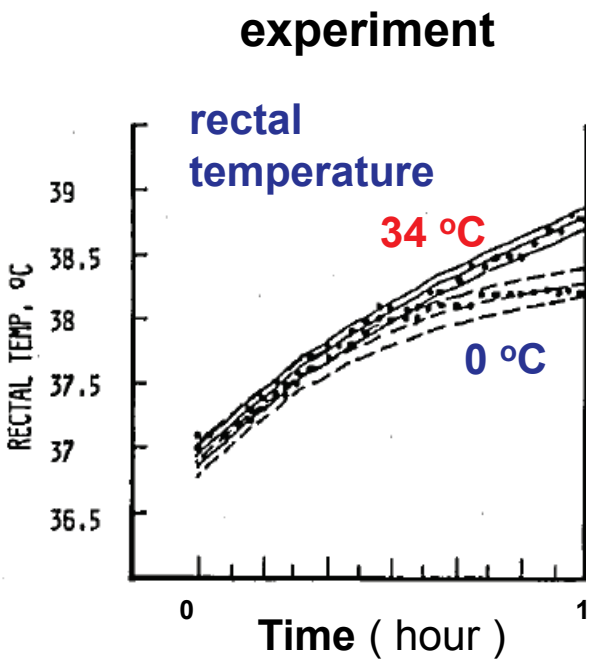
Reality check – experimental evidence

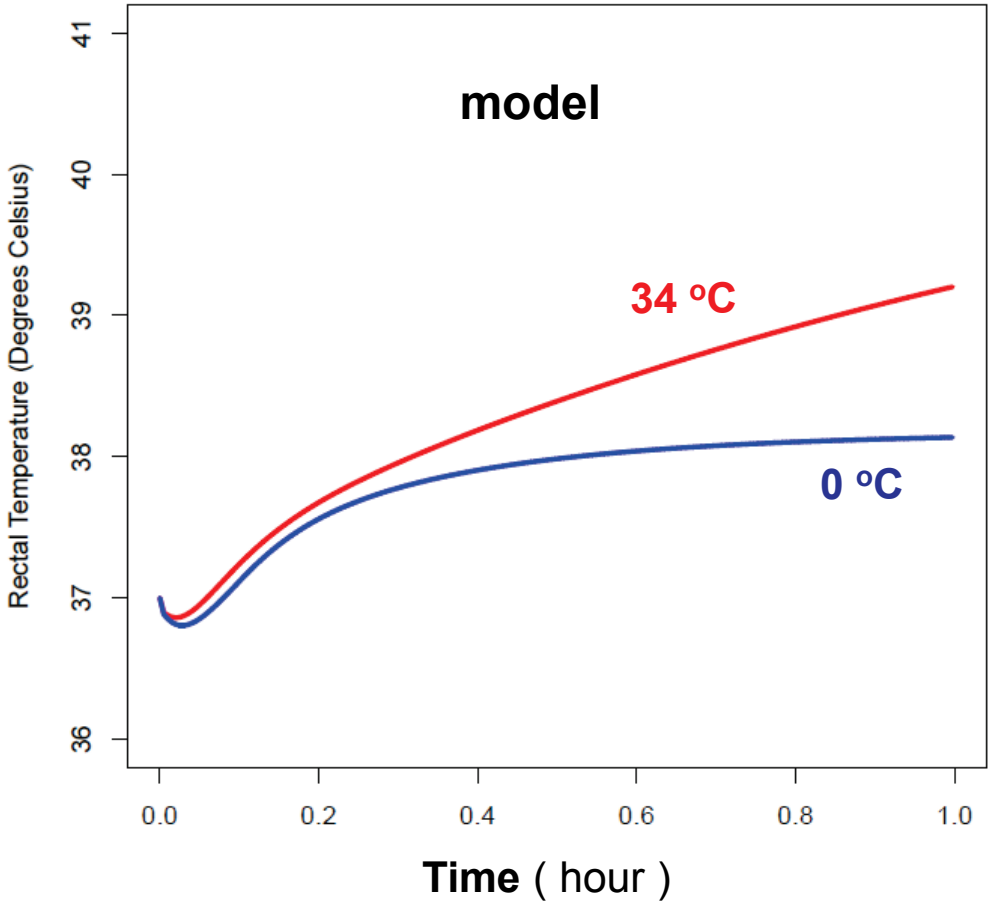
(experiments Young et al., J Appl Physiol, 1986)



moved from 24 °C
to 5 °C,
resting young males

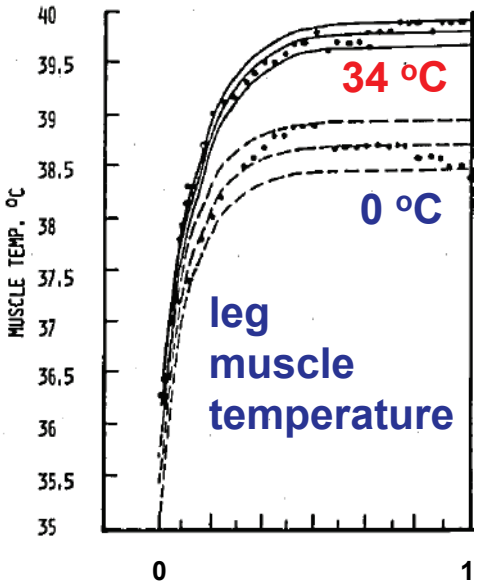
Reality check – experimental evidence
(experiments Claremont et al., Med Sci Sports, 1975)

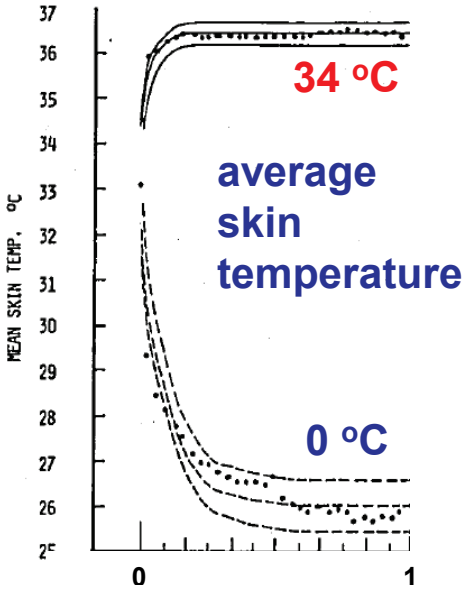




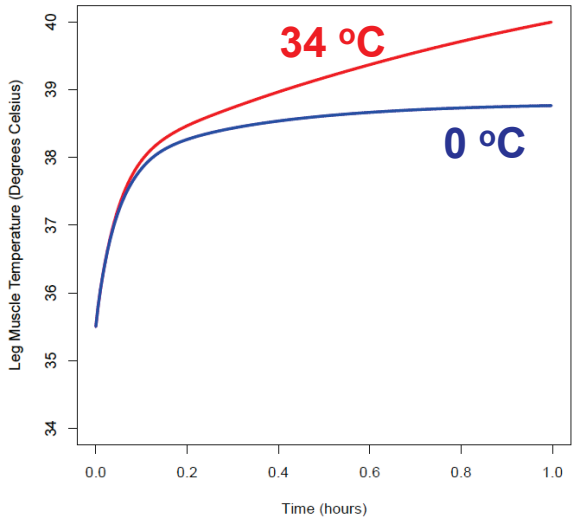
One hour exercise on bicycle ergometer

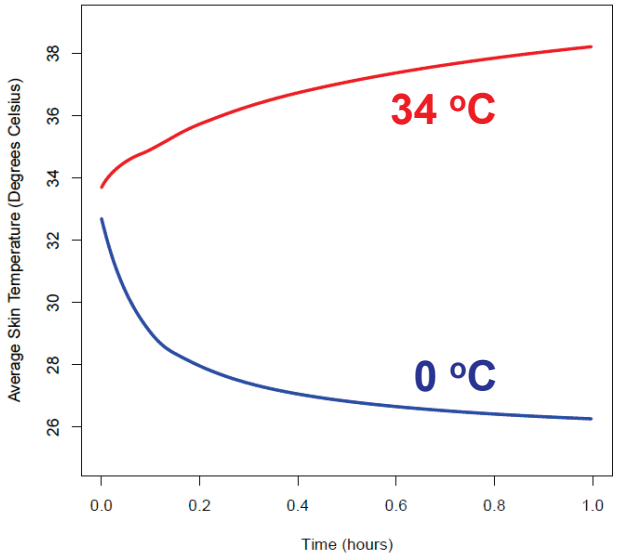
Reality check – experimental evidence
(experiments Claremont et al., Med Sci Sports, 1975)





Time (hour)

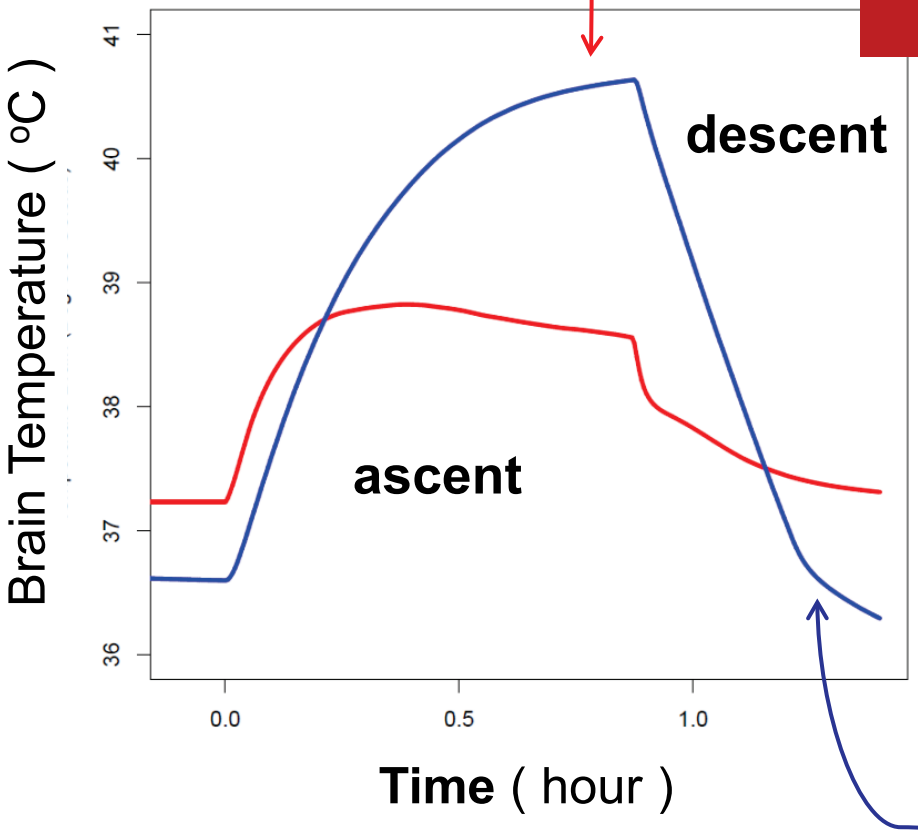




Summary: Striking Result

Warm 18 °C / Freezing -4 °C on summit mountain

It is possible that a paradoxical situation develops (but a computer model is a computer model and not a pro cyclist)



Teammates

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Marjolein Verhoeven

Hans van Beek

Sponsors

Three centres funded via the Netherlands Genomics Initiative (NWO) supported related projects :

Netherlands Bioinformatics Centre

Centre for Medical Systems Biology

Netherlands Consortium for Systems Biology

Farahaniza Supandi is supported by the University and Government of Malaysia

2 July 2015

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