«Θερμορύθμιση και Άσκηση: σημεία καμπής και διχογνωμίες»

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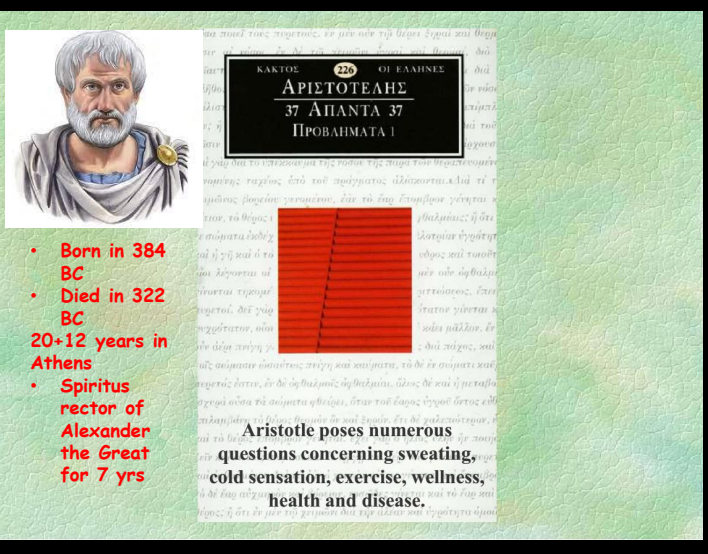
Εθνικό και Καποδιστριακό Πανεπιστήμιο Αθηνών

1

Turning point 1



- Born in 384 BC
- Died in 322 BC

20+12 years in Athens

- Spiritus rector of Alexander the Great for 7 yrs

Aristotle poses numerous questions concerning sweating, cold sensation, exercise, wellness, health and disease.

2

Theoretical context and methodology

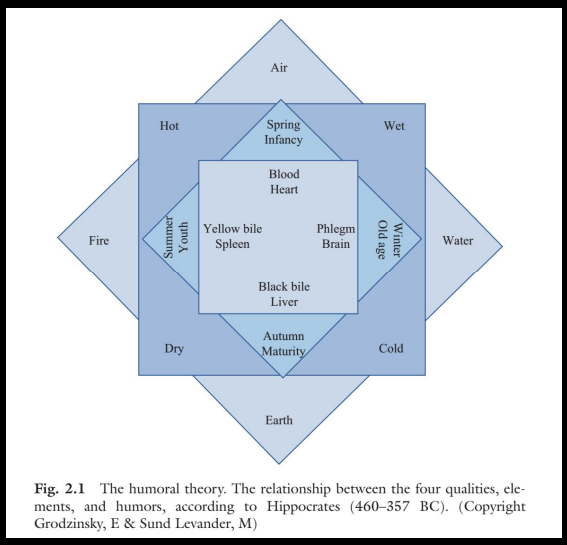


Fig. 2.1 The humoral theory. The relationship between the four qualities, elements, and humors, according to Hippocrates (460–357 BC). (Copyright Grodzinsky, E & Sund Levander, M)

- Observation
- Inductivism
- Teleology

3

Aristotle's questions

▪ ***"Why intermittent type of work induces higher sweating than continuous exercise?"*** *"Should sweating be accumulating while resting? In addition, a bout of exercise following a break is forcefully excreting sweating. On the contrary, continuous exercising dries sweating, as sun does." (Aristotle)*

4

Turning point 2

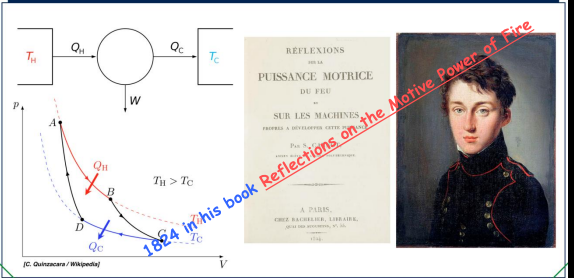
Evolution of inductivism

- *Observational factual knowledge can be augmented by active experimentation (Roger Bacon 1214 - 1292)*
- *Introduction of Euclid's principle of falsification by Robert Grossetest (1168 - 1253) in order to supplement scientific hypotheses*
- *Teleological explanation is totally excluded (Galileo Galilei 1561- 1626)*
- *Francis Bacon criticizes (1561 - 1626) haphazard data collection, hasty generalization, overuse of enumerative inductions*
- *Creative imagination, interpretations contigent to revision (Isaac Newton, 1642 - 1727)*

5

Turning point 3

Nicolas Léonard Sadi Carnot (1796-1832)



- James Currie (1767-1805) grasped the link between evaporation and cooling, but could not explain what actually happened .
- **The first law of thermodynamics states that, when energy passes into or out of a system (as work, heat, or matter), the system's internal energy changes in accordance with the law of conservation of energy.**
- **The second law of thermodynamics states that in a natural thermodynamic process, the sum of the entropies of the interacting thermodynamic systems never decreases. A common corollary of the statement is that heat does not spontaneously pass from a colder body to a warmer body.**

6

Turning point 4

- 1600: Thermoscope detecting human body sensible heat (open thermometer, Galileo)
- 1654: Scaled tubes (thermometer) filled with alcohol (Ferdinand II de' Medici, Grand Duke of Toscani)
- Mid 1700: Fahreneheit (German) and Celsius (Swedish) scales were agreed
- 1821: Thermocouples were invented (Thomas Seebck, Esthonia)
- 1869, 1900: Axillary, Rectal – Oral temperatures recorded
- 1964: Tympanic membrane radiometer (Theodor Benzinger, USA)

Measuring Heat

Understanding fever and body temperature, Edited by Grodzinsky E., and Levander MS, 2020

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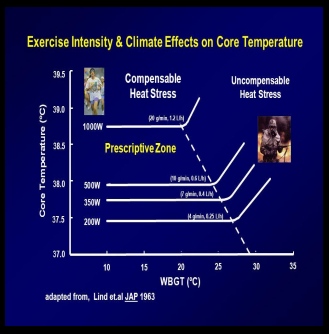
Turning point 5

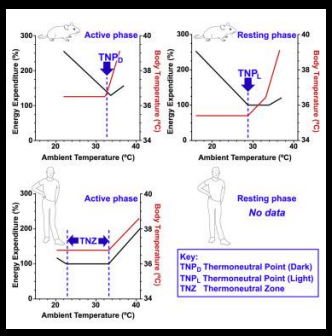
- 1849: Regulation of the internal environment (Claude Bernard)
- 1926: The term of homeostasis was introduced (Walter Cannon)
- 1932: higher brain function is required for a most stable internal environment (Barcroft)

Cannon, W.B., (1932). The Wisdom of the Body. New York: W. W. Norton. pp. 177–201.

8

Thermoneutral zone, rest & environment





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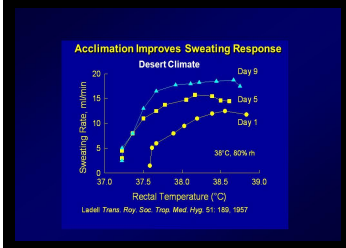
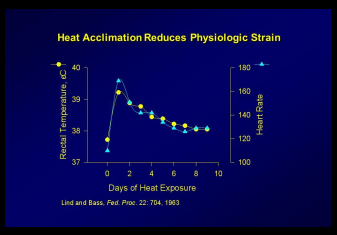
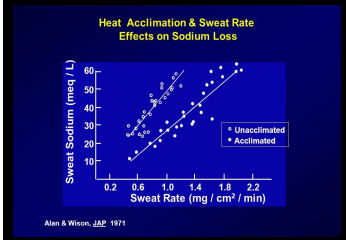
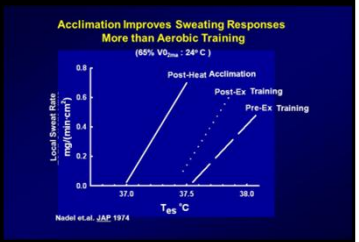
Exercise and temperature regulation









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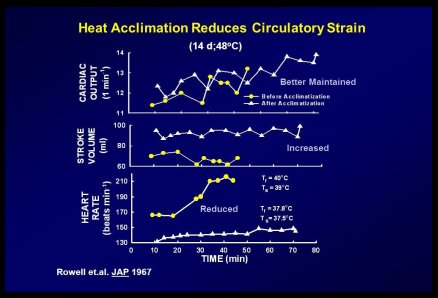
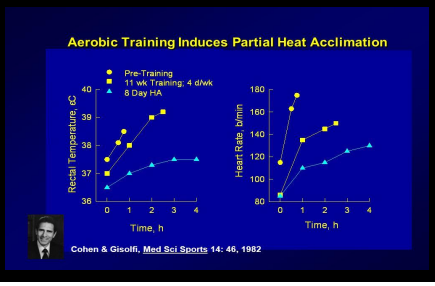
The role of cardiovascular system





Acta physiol. scand. 1962. 56. 120—129

From the Zoophysiological Laboratory A, University of Copenhagen, Denmark

Body Temperature During Work at Different Environmental Temperatures

By

Bodil Nielsen and Marius Nielsen

Received 22 February 1962

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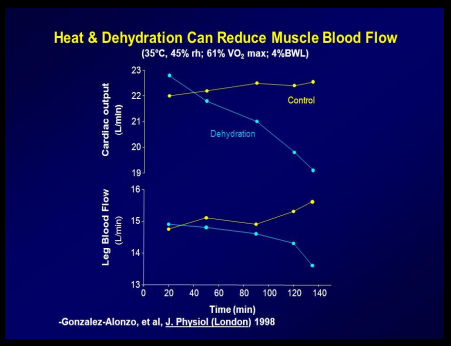
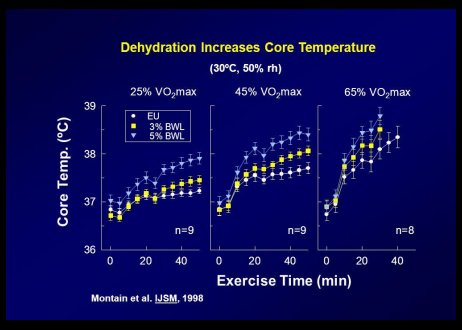
The role of dyhydration





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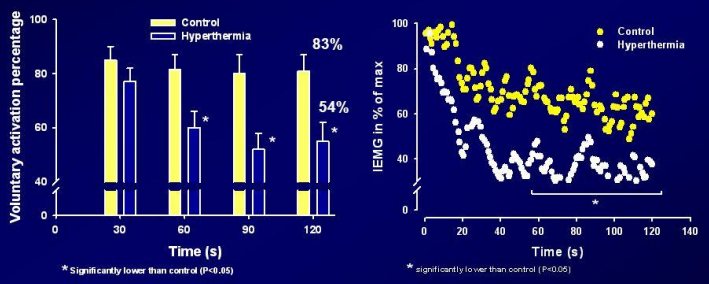
The role of CNS

Hyperthermia Reduces Voluntary Muscle Force Activation

Exercise to exhaustion (60%VO_{2max}) in hot or temperate;
sustained MVC knee, voluntary activation by electrical stimulation to nervus femoris

(Control T_c = 38ºC; Hyperthermia T_c = 40ºC)



Nybo & Nielson JAP 2001

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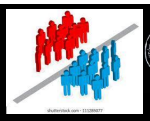
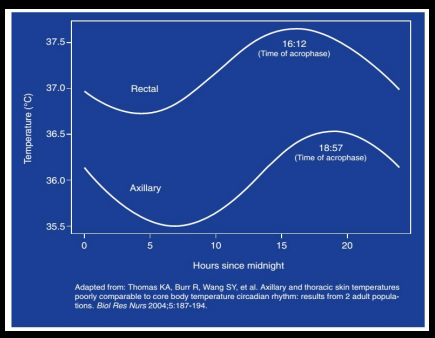
Disunity 1 - Πρώτη Διχογνωμία



- Where is the right place to measure core temperature ??
- Which temperature is more crucial?



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Selective brain cooling?

- ***"Why people sweat more in the face?*** *(Aristotle)"*
- *"Should it be that head is rich in fluids, pores, veins, and vessels ."* *(Aristotle)* ***or***
- *"Should it be that selective brain cooling does exist in humans as Cabanac (1978) heretically alleges ."*
- *During the last 25 years 102 articles have been published investigating the question: "Is tympanic temperature representative index of regulated brain temperature? " 59% of these articles provide positive answer whereas the resting 41% give an emphatic no.*

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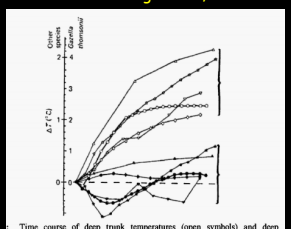
SELECTIVE BRAIN COOLING AND THERMOREGULATORY SET-POINT

Michel Cabanac

Département de Physiologie, Faculte de Medecine, Universite Laval Quebec QC, Canada G1K 7P4

Freund Publishing House, 1998



Time course of deep trunk temperatures (open symbols) and deep intracranial temperatures (solid symbols) during muscular exercise in various mammals. Deep trunk temperature was recorded in the rabbit from the rectum, in Thomson's gazelle and dog (stars) from the carotid artery, in the dog from the spinal cord, and in the human study from the esophagus. Intracranial temperature was hypothalamic temperature in animal experiments and tympanic temperature in humans. Time scales were equated arbitrarily because the duration of exercise varied from 7 min (Thomson's gazelle) to 42 min (humans). △▲, *Gazella thomsoni* /26/; ▽▼, *Oryctolagus cuniculus* /27/; ◇◆ *Canis familiaris* /28/; ☆★ *Canis familiaris* /29/; ○● *Homo sapiens* /30/. From Cabanac and Caputa 1979 /30/.

J. Physiol. **(1979), 286,** *pp.* 255–264
With 4 text-figures
Printed in Great Britain

NATURAL SELECTIVE COOLING OF THE HUMAN BRAIN: EVIDENCE OF ITS OCCURRENCE AND MAGNITUDE

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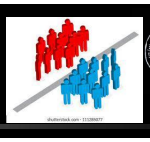
Disunity 2 – Δεύτερη Διχογνωμία
The mystery of active vasodilation



TEMPERATURE
2017, VOL. 4, NO. 1, 41–59
http://dx.doi.org/10.1080/23328940.2016.1200203

COMPREHENSIVE REVIEW

OPEN ACCESS

Current concepts of active vasodilation in human sk

Brett J. Wong and Casey G. Hollowed

Department of Kinesiology & Health, Georgia State University, A

hypothesized to operate through a co-transmission mechanism. To date, mechanisms of cutaneous active vasodilation remain equivocal despite many years of research by several productive laboratory groups. The purpose of this review is to highlight recent advancements in the field of

dilation is the co-tr… theory.[1] The original proposition for th… suggested that acetycholine and an unkno… transmitter are released from sympathetic nerve terminals, where acetylcholine mediates sudomotor activity (sweating) and the unknown neurotransmitter mediates cutaneous vasodilation. While the general notion of acetylcholine mediating a large portion of sudomotor activity is fairly well established, identification of the unknown co-transmitter responsible for cutaneous vasodilation has proven to be elusive.

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The mystery of active vasodilation

- Increased blood flow during heating is of reflex origin and is mainly directed to the Skin
- The reflex is of sympathetic nature
- Cutaneous vasodialation (active vasodialtion) and sweating appear to occur simultaneously
- Both increases may be mediated by cholinergic mechanisms

What is the nature of the vasodilator (s)??????
NO??
Histamine??
Prostaglandins???
Neurokinin – 1???

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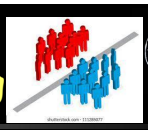
Disunity 3 – Τρίτη Διχογνωμία
Does thermoregulation drives sleeping or vice versa?



"Why people sweat more while sleeping?"

"Should it be attributed to antiperistasis, a phenomenon where heat is compressed from the surrounding cold. Indeed, internally accumulated heat extracts (body) fluids." (Aristotle)

- *" It has found that onset of sleep is characterized by a wave of sweating which however fades away when body temperature drops (Henane et al. (1977)). Sleep is associated with consolidated inactivity, which results in decreased heat production and thus human body has the opportunity to dissipate heat during wakefulness" (Heller et al., 1996).*

Thus, it appears that this ol… deplored scientists fo…

The humoral theory understood sweating as a means of excreting an excess or surplus from the body in order to restore balance. As fevered individuals began to recover, feel cooler, and indeed seem cooler to the observer's hand when they sweated, it was believed that the offending humors were leaving them in the sweat. Hence, according to the humoral

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Set point: Is it a winning or an elusive point?

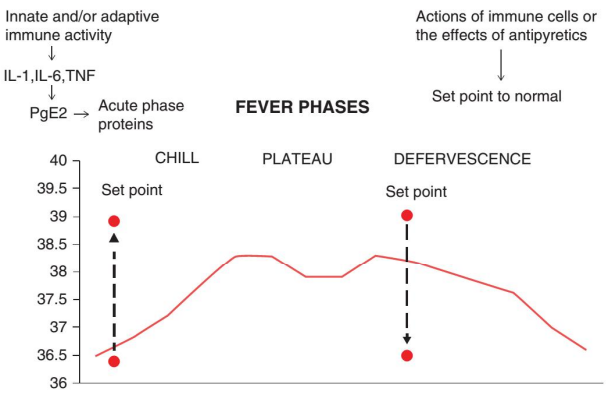

Fig. 6.4 Fever phases related to immune activity. IL interleukin, TNF tumor necrosis factor, PG prostaglandin. 40 °C (104 °F); 39.5 °C (103.1 °F); 39 °C (102.2 °F); 38.5 °C (101.3 °F); 38 °C (100.4 °F); 37.5 °C (99.5 °F); 37 °C (98.6 °F); 35.5 °C (97.7 °F); 36 °C (96.8 °F). (Copyright Grodzinsky, E and Sund Levander, M)

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What is regulated during exercise?

- Why core temperature is always elevated even in cold environment
- Why fatigue coincides with a individual core temperature
- Why activation of heat dissipating mechanisms fall behind the activation of heat generating mechanisms

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Invited Review

J Appl Physiol 100: 1332–1337, 2006;
doi:10.1152/japplphysiol.01068.2005.

HIGHLIGHTED TOPIC | *A Physiological Systems Approach to Human and Mammalian Thermoregulation*

A theoretical consideration of the means whereby the mammalian core temperature is defended at a null zone

John Bligh
Little Garth, High Street, Harston, Cambridge, United Kingdom

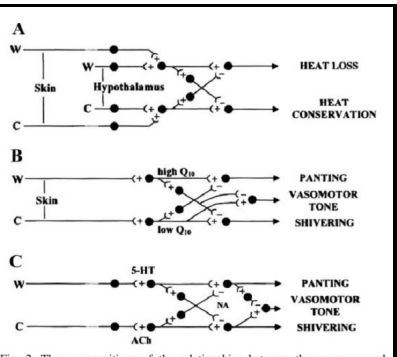
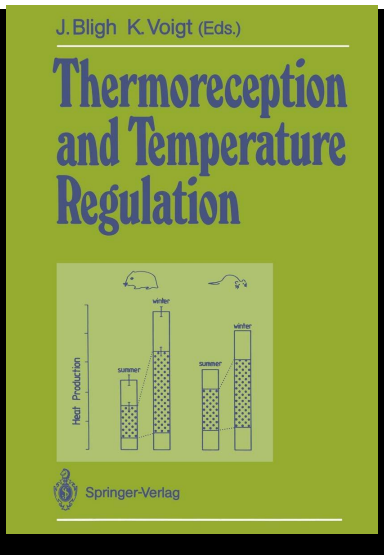


Fig. 2. Three propositions of the relationships between thermosensor and thermocorrecting effectors that were derived quite independently from quite different considerations. *A*: the interpretation by Wyndham and Atkins (21) of studies of homeothermy in humans [as reexpressed by Bligh (2)]. *B*: a neuronal model by Hammel (9, 10) based largely on unit activity studies. *C*: the neuronal model of Bligh et al. (4) and Bligh (2) based on the central effects of putative transmitter substances on the homeothermy of sheep. 5-HT, 5-hydroxytryptamine; NA, norepinephrine; ACh, acetylcholine.



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Is there any inhibition?

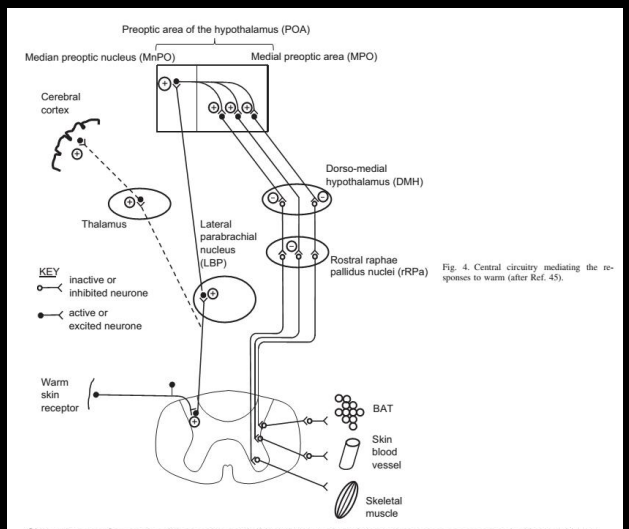

Fig. 4. Central circuitry mediating the responses to warm (after Ref. 45).

Charkoudian N. Skin blood flow in adult human thermoregulation: how it works, when it does not, and why. *Mayo Clin Proc* 78: 603–612, 2003.

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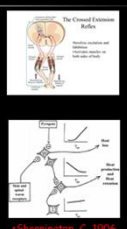
Cross inhibition

Professor Charles Scott Sherrington

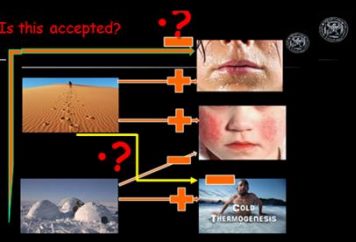


•Sherrington C, 1906

Is there any experimental evidence?

- The possible central role of GABA in thermoregulation in the sheep
- Injections of GABA and its agonist muscimol into a lateral cerebral ventricle of sheep depressed both evaporative heat loss (40 and 58% respectively) at 41°C ambient temperature (Ta) and metabolic heat production (27 and 32% respectively) at 3°C Ta. The intracerebroventricular (ICV) injection of the GABA antagonist, bicuculline (Bi), prior to an ICV injection of either serotonin (5-HT) or carbamyl choline (CCh) prevented the inhibitory effects of an ICV injection of 5-HT at 3°C or CCh at 41°C on heat production and heat loss respectively [Bligh et al., J. Physiol., Lond. 212, 377-392 (1971)]
- Simultaneously the inhibitory effects of hot and cold ambient temperatures on heat production and heat loss, respectively, were blocked and both the heat production and heat loss pathways were activated concurrently. These results suggest that GABA may be a terminal transmitter of reciprocal inhibition between the two major thermosensor to thermoregulatory effector pathways in the sheep.
- Add Romain
- Smullin DH, Bligh J., J of Thermal Biology, 1989
- Review by Bligh J., Mammalian Homeothermy: An Integrative Thesis, J. Thermal Biology, 1998

•Is this accepted?



•Reciprocal Cross Inhibition or 'Cross - Talk'

Is there any evidence in humans? No
How do we study this?

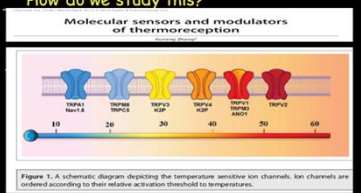


Figure 1. A schematic diagram depicting the temperature sensitive ion channels. Ion channels are ordered according to their relative activation threshold to temperatures.

•Molecular sensors and modulators by Xuming Zhang, 2015

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Exercise and cross inbibition

The effect of menthol applicationto the skin on Sweating rate and the reciprocal cross inhibitiontheory

- Exercise → ↑Tcore rise → ↑Swr increase
- Skin Cold TPRM8, menthol application → ↑VO2 rise, ↑CVtone rise

(Schafer et al. 1986, Kuno et al. 2006)

Hypothesis: Exercise and menthol application

VO2 rise, Cutaneous Vascular (CV) tone enhanced and limited Sweat Rate (Wyss 1998, Ravanelli & Binns 2016)

The effect of menthol applicationto the skin on Sweating rate and the reciprocal cross inhibitiontheory

Table 1 Age, anthropometric values and maximal oxygen uptake ($\dot{V}O_2$max) for the physical education students (CON, $n = 8$) and the swimmers (SW, $n = 8$)

	CON	SW
Age (years)	27.7 (3.4)	21.3 (2.1)
Stature (cm)	182.4 (6.9)	181.8 (7.0)
Body mass (kg)	73.9 (5.6)	76.6 (5.2)
Body fat (%)	8.4 (2.1)	11.8 (2.7)#
$\dot{V}O_2$max (mL kg^{-1} min^{-1})	42.1 (3.1)	46.7 (4.2)*

Values are means (SD)

* Significant differences between groups, $p < 0.05$; # $p = 0.07$

Kounalakis S., Botonis P.G., Koskolou M. and Geladas N., The effect of menthol application to the skin and Sweating rate response during exercise in swimmers and Controls, ECAP, 2010

Methods

Experimental protocol

Cycling at 60% of aerobic power so long as to reach 38°C in Tre, Ta=24 °C

- Control
  - No Menthol
  - Menthol — Creamy sediment (4.6 gr/ 100ml water), All over body except areas of sensors positions
- Swimmers
  - No Menthol
  - Menthol — Creamy sediment (4.6 gr/ 100ml water), All over body except areas of sensors positions

Tre
ΔT_{SKIN}
Sweating rate

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Exercise and cross inhibition

The effect of menthol applicationto the skin on Sweating rate and the reciprocal cross inhibitiontheory

•Results:

Kounalakis S., Botonis PG., Koskolou M. and Geladas N., The effect of menthol application to the skin and Sweating rate response during exercise in swimmers and Controls, ECAP, 2010

Table 2 Cardiovascular and thermoregulatory variables during cycling for the physical education students (CON, $n = 8$) and the swimmers (SW, $n = 8$), with (M) and without (NM) menthol application

	CON		SW	
	NM	M	NM	M
$\dot{V}O_2$ (ml min^{-1})	1,778 (310)	1,907 (334)	2,062 (280)	2,092 (380)
$\dot{V}O_2$ max (%)	57 (3)	61 (2)	57 (3)	58 (2)
HR (beats min^{-1})	157 (14)	156 (12)	140 (7)	139 (7)
Tre rest (°C)	37.1 (0.3)	37.1 (0.3)	37.3 (0.3)	37.3 (0.3)
Threshold for Tre increase (min)	6.5 (1.0)	4.7 (1.3)*	5.5 (1.1)	2.2 (1.1)*†
Tre increase (°C min^{-1}), value × 100	2.31 (0.73)	2.99 (0.73)*	2.78 (0.82)	3.95 (1.23)*†
Exercise time to reach 38°C (min)	27.5 (5.4)	22.6 (6.0)*	33.5 (16)	22.8 (8.9)*
Threshold for sweating (min)	3.25 (1.3)	7.3 (2.1)*	4.1 (3.2)	17.0 (3.5)*†
Threshold ΔTre for sweating (°C)	0.23 (0.06)	0.36 (0.09)*	0.11 (0.06)†	0.61 (0.13)*†
SwR increase (g min^{-1} cm^{-2} °C^{-1})	6.47 (0.41)	2.25 (0.82)*	6.12 (0.42)	2.24 (0.76)*

Values are means (SD)

$\dot{V}O_2$ maximal oxygen uptake, HR heart rate, Tre rectal temperature, SwR sweating rate

* Significantly different from NM, $p < 0.05$; † Significantly different from CON, $p < 0.05$

•Rectal temperature increase was higher in menthol than in no menthol conditions
•Time to increase Tre at 38 °C was less in menthol than in no menthol conditions
That was due to:

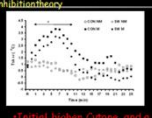
The effect of menthol applicationto the skin on Sweating rate and the reciprocal cross inhibitiontheory

- Exercise → ↑Tcore rise → ↓Swr no increase but decrease
- Skin Cold TPRM8, menthol application → ↑VO2 rise, ↑CVtone rise

Hypothesis: Exercise and menthol application

VO2 rise, Cutaneous Vascular (CV) tone enhanced and limited Sweat Rate (Wyss 1998, Ravanelli & Binns 2016)

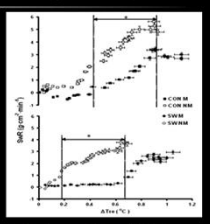
The effect of menthol applicationto the skin on Sweating rate and the reciprocal cross inhibitiontheory



•Initial higher Cvtone and a tendency for higher VO2 in menthol than in no menthol conditions as in animals (Flynn 2007)

•AND

INHIBITION OF SWEATING (rate and threshold) in the the menthol conditions



Kounalakis S., Botonis PG., Koskolou M. and Geladas N., The effect of menthol application to the skin and Sweating rate response during exercise in swimmers and Controls, ECAP, 2010

The effect of capsaicin application on the skin at rest and the reciprocal cross inhibition theory

Effects of capsaicin application on the skin during resting exposure to temperate and warm conditions
Botonis P., Miliotis P, Kounalakis S, Koskolou & Geladas N., Scan J Med & Sc in Sports, 2018

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Is there any significance?

Non-steroidal anti-inflammatory drugs on core body temperature during exercise: A systematic review

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ABSTRACT

Background/Objective: Because of their anti-pyretic effects, some individuals prophylactically use non-steroidal anti-inflammatory drugs (NSAIDs) to blunt core temperature (Tc) increases during exercise, thus, potentially improving performance by preventing hyperthermia and/or exertional heat illness. However, NSAIDs induce gastrointestinal damage, alter renal function, and decrease cardiovascular function, which could compromise thermoregulation and increase Tc. The aim of this systematic review was to evaluate the effects of NSAIDs on Tc in exercising, adult humans.

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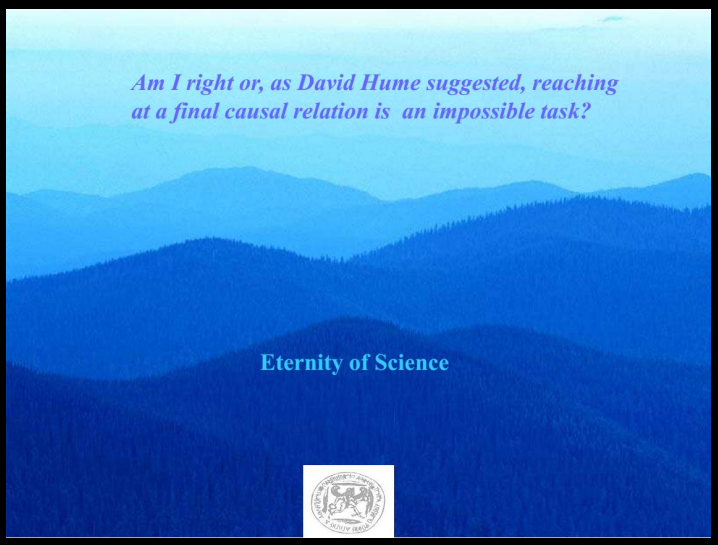
Data which are not entailed in a theory are apples on the ground of an orange field



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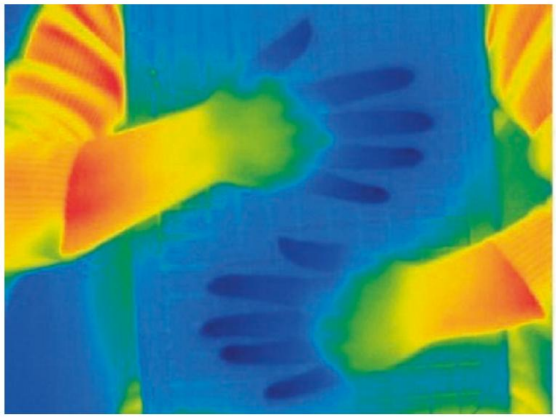
ΕΥΧΑΡΙΣΤΩ



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