In general…

People do not like cold!!!

… and better choose warm
Cold  Wet  Nasty

My field of expertise

What we already know

Prolonged exposure to a severe cold environment causes marked whole-body cooling, defined as a decrease in core temperature, which can impair motor and cognitive performance by altering neural drive through central and peripheral failure (Brazaitis, et al., 2014; Cohill, et al., 2011; Giesbrecht, et al. 1995; Rutkove et al., 1997; Solianik et al., 2014).
Even exposure to less severe cold, which does not lower core temperature markedly, may produce cognitive (Palinkas, 2001; Mäkinen et al., 2006; Muller et al., 2012) and physical (Drinkwater & Behm, 2007) decrements, which may adversely affect performance and health (Tanaka et al., 1993; Palinkas, 2001).
The origin of thermoregulation in non-cold-adapted humans involves metabolic, hypothermic and insulative patterns of physiological responses to exposure to acute cold.

Evidently, the $T_{sk}$ decreases to a greater extent that does the $T_{re}$, whereas MHP increases.

**Type of cold resistance**

<table>
<thead>
<tr>
<th>Type</th>
<th>Rectal T</th>
<th>Skin T</th>
<th>MHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic type of resistance</td>
<td></td>
<td>↑</td>
<td>↑</td>
</tr>
<tr>
<td>Insulative type of resistance</td>
<td></td>
<td>↓</td>
<td></td>
</tr>
<tr>
<td>Hypothermic type of resistance</td>
<td>↓</td>
<td></td>
<td>↓</td>
</tr>
</tbody>
</table>

**Subtypes**

- Insulative-hypothermic: ↓ ↓ ↑
- Metabolic-insulative:     – ↓ ↑

*MHP - Metabolic heat production*  
*Makinens, Frontiers in Bioscience, 2010*
Despite the common opinion that gender affects the body’s response to cold (Launay and Savourey, 2009; Makinen, 2010), most thermal research has been conducted in men, and our general understanding of the responses to cold stress is based on the men (Solianik et al., 2014).

What is the main reason for this?

A total of 2,366,968 (39%) participants were female and 3,709,612 (61%) were male.

The average percentage of female participants per article across the journals ranged from 35% to 37%.
...and may have potentially led to the scarcity of females participating in these studies.

Costello et al., 2014

What we already know

Differences in thermoregulation between men and women are related mainly to anthropometric differences:

- Women have more fat mass, whereas men have more skeletal muscle mass (Anderson, 1999);
- The body surface area-to-mass ratio is larger for women (Chi et al., 2012).

As a result, in cold-water (20–24°C) immersion, women cool at faster rates than men (McArdle et al., 1984).
In contrast to aforementioned observations, gender-specific difference disappeared when an acute cold stress was induced by immersion in 14°C water from normothermic conditions (Solianik et al., 2014, 2015).

Specifically, men relied more on metabolic strategies and women – on insulative strategies. Men used shivering thermogenesis more than women.

This discrepancy in $T_{re}$ cooling rate may be explained by different water temperature used i.e. 14°C vs. 20-24°C.
Why 14°C water temperature?

Šramek et al., Eur J Appl physiol 2000

The temperature of the water bath was 14°C and a head-out water immersion procedure continued until the Tr had decreased to 35.5°C or until 170 min of the Tr had elapsed in total (120 min maximum of total immersion time), at which time the immersion ended.

solanik et al. Cryobiology 2014

Why 3-h in 14°C water temperature?

The temperature of the water bath was 14°C and a head-out water immersion procedure continued until the Tr had decreased to 35.5°C or until 170 min of the Tr had elapsed in total (120 min maximum of total immersion time), at which time the immersion ended.
Despite the lack of difference in the cold strain index between men and women, the neuroendocrine and immune responses differed. Men exhibited a higher epinephrine level and a lower TNF-a level during cold stress.

Two sampling time points is the main limiting factor in such studies.

It is known, that in vitro mild hypothermia can suppress inflammatory reactions, and moderate hypothermia can delay the induction of pro-inflammatory cytokines (Kimura et al., 2002).

Solianik et al., 2014

### Stress and immune response

<table>
<thead>
<tr>
<th>Task</th>
<th>Before</th>
<th>After</th>
<th>Δ %</th>
<th>Before</th>
<th>After</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time, s</td>
<td>0.99 ± 0.07</td>
<td>0.69 ± 0.06**</td>
<td>-31.3%</td>
<td>0.61 ± 0.07</td>
<td>0.67 ± 0.10</td>
<td>9.3%</td>
</tr>
<tr>
<td>Errors, %</td>
<td>5.2 ± 3.2</td>
<td>4.2 ± 4.4</td>
<td>22.2%</td>
<td>3.5 ± 3.0</td>
<td>4.0 ± 3.0</td>
<td>-12.8%</td>
</tr>
</tbody>
</table>

Forward digit span:

| Mean digit span, sec | 6.3 ± 0.56 | 6.54 ± 0.52** | -4.0% | 6.71 ± 0.57 | 6.59 ± 0.73 | -1.7% |

Percent change recognition:

| Correct answers, sec | 7.00 ± 3.04 | 6.88 ± 1.17** | -2.1% | 8.00 ± 7.64 | 8.17 ± 2.25** | 2.1% |

Data are presented as mean ± standard deviation. Δ% denote significant differences of P ≤ 0.05 and P ≤ 0.02, respectively between before and after intervention.

### Motor performance

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Before</th>
<th>After</th>
<th>Δ %</th>
<th>Before</th>
<th>After</th>
<th>Δ %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVC Nm</td>
<td>177.5 ± 18.3</td>
<td>162.6 ± 29.8**</td>
<td>-8.4%</td>
<td>130.4 ± 25.1**</td>
<td>136.1 ± 32.0**</td>
<td>4.6%</td>
</tr>
<tr>
<td>CO2</td>
<td>1.80 ± 0.00</td>
<td>1.80 ± 0.01</td>
<td>0.0%</td>
<td>0.99 ± 0.04</td>
<td>0.99 ± 0.02</td>
<td>0.0%</td>
</tr>
<tr>
<td>PL Nm</td>
<td>214.4 ± 47</td>
<td>214.5 ± 56</td>
<td>0.0%</td>
<td>202.1 ± 39</td>
<td>192.2 ± 38</td>
<td>-4.7%</td>
</tr>
<tr>
<td>PBO Nm</td>
<td>114.7 ± 27.5</td>
<td>94.1 ± 23.0**</td>
<td>-20.7%</td>
<td>110.4 ± 15.4</td>
<td>83.9 ± 12.1**</td>
<td>-27.6%</td>
</tr>
<tr>
<td>PITTROM Nm</td>
<td>385.1 ± 22.1</td>
<td>371.7 ± 21.5**</td>
<td>-3.5%</td>
<td>300.7 ± 20.5**</td>
<td>332.3 ± 20.2**</td>
<td>10.1%</td>
</tr>
<tr>
<td>CO2 (%)</td>
<td>10.4 ± 1.2</td>
<td>10.4 ± 1.3</td>
<td>0.0%</td>
<td>10.4 ± 1.2</td>
<td>10.4 ± 1.3</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH10</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH20</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH30</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH40</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH50</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH60</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH70</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH80</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH90</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
<tr>
<td>TH100</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
<td>100 ± 100</td>
<td>100 ± 100</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Data are presented as mean ± standard deviation. Δ% denote significant differences of P ≤ 0.05 and P ≤ 0.02, respectively between before and after intervention.
Resistance to fatigue

**Male**

**Female**

*Why it's so?*

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Solianik et al. Cryobiology 2014
Motor and cognitive performance response to cold stress did not differ between the FC and SC groups.

Stress markers (increases in cortisol, epinephrine and norepinephrine concentrations) did not differ between the FC and SC groups.

In hypothermia (male subjects)

Stress markers (increases in cortisol, epinephrine and norepinephrine concentrations) did not differ between the FC and SC groups.

Motor and cognitive performance response to cold stress did not differ between the FC and SC groups.

FC - fast cooling group n=20
SC - slow cooling group n=20

Brazaitis et al., PlosOne 2014
Two strategies for the acute response to cold exposure but one strategy for the response to heat stress

Marius Brazaitis¹, Nerijus Elmantas¹, Laura Dainusevičiute², Astra Vitkauskienė³, Henrikas Paulauskas¹, & Albertas Skurvydas⁴

¹Sports, Science and Innovation Institute, Lithuanian Sports University, Kaunas; ²Department of Educational Studies, Kaunas University of Technology, Kaunas, and ³Department of Laboratory Medicine, Medical Academy, Lithuanian University of Health Science, Kaunas, Lithuania

Key remarks

In hyperthermia (T_re 39.5°C; male subjects)

• The increase in cortisol, epinephrine, norepinephrine, and corticosterone concentrations after passive body heating did not differ between the FC and SC groups;

• Heat stress did not change indicators of innate and specific immunity in the FC or the SC group;

• Heat stress did not affect motor and cognitive function in either group.

FC – fast cooling group n=20
SC – slow cooling group n=20

Brazaitis et al., Int J Hyperthermia 2015
ACTN3 577XX null genotype is common in places with lower annual temperature (Friedlander et al., 2013).

α-actinin-3 deficiency changes cellular Ca\(^{2+}\) handling that could be helpful in adapting the muscles to cold environments and provide a survival advantage in cold climates (Head et al., 2015).

Background

Even without cold acclimation, fast skeletal muscles of Actn3 KO mice have upregulated cellular Ca\(^{2+}\) cycling and heat generation at rest (Head et al., 2015) which provides a mechanistic insight on enhanced human survival in cold environments and positive selection of the 577X null allele.

We hypothesized that the body temperature would be better preserved in ACTN3 577XX null genotype than in RR individuals.
Results

Figure 1. Decline rate in rectal (T\text{re}) skin (T\text{sk}) and intramuscular (T\text{mu}) temperatures between ACTN3 genotype groups. T-test: A, T\text{re} P = 0.002; B, T\text{sk} P = 0.033; C, T\text{mu} P = 0.001.

RR group (n=27)
XX group (n=15)

Venckūnas et al., unpublished data

Results

Figure 2. Values in metabolic activation in response to cooling between ACTN3 genotype groups. * P < 0.05, compared with baseline. Values are mean ± SEM. HR, heart rate; MHP, metabolic heat production; RER, respiratory exchange ratio.

Venckūnas et al., unpublished data
Results

![Graph showing shivering EMG amplitude (RMS, root mean square) (A) and mean frequency (MnF) (B) in ACTN3 genotype groups.]( Venckunas et al., unpublished data)

Figure 3. Shivering EMG amplitude (RMS, root mean square) (A) and mean frequency (MnF) (B) in ACTN3 genotype groups.

Key remarks

Temperature was better preserved in the XX group.

This was not due to differences in body composition, e.g. more fat.

Also, it was not accompanied by exaggerated changes in ventilatory or cardiovascular parameters.

Shivering was in fact decreased in XX and clearly cannot explain the improved cold tolerance.

Thus increased SR Ca$^{2+}$ cycling is a likely mechanism.

Venckunas et al., unpublished data
In contrast to $T_{re}$ cooling rate from normothermic conditions women had a greater post exercise recovery cooling rate (decrease in $T_{re}$) than men in cold air.

In our other study

Temperatures in active and inactive muscles in women stay higher for a longer time after dynamic exercise compared with men (Kenny and Jay, 2007), suggesting a larger blood circulation in skin and muscles recovering from exercise (Halliwill, 2001).
It is also interesting note that during exercise at similar relative exercise intensities, core temperature in women decreases after 2 hr while men maintain their core temperature during that time (Graham, 1983). This is another indication that heat loss exceeds heat production and heat conservation faster during exercise in a cold environment in women than in men.

Core temperature thresholds for the onset of thermoregulatory effectors to prevent body cooling occurred at higher core temperatures in the luteal phase compared with the follicular phase.

What we already know

Discharge frequencies at different skin temperatures of thermoreceptors, along with potential transient receptor potential (TRP) channels associated with receptor function (Craig, 2002; Vay et al., 2012; Tansey & Johnson, 2015).
13.11.2017

... and this effects sex-specific thermoregulatory behavior

This is...

(a) women sensed skin cooling more quickly in the luteal phase (Kenshalo, 1966)

(b) women had a higher skin temperature preference in the luteal phase (Cunningham and Cabanac, 1971).

From Wikimedia Commons, the free media repository

It is worth to note that

At warmer water temperatures, women required a warmer water temperature than men did during water immersion that could be tolerated for 3 hr (Rennie et al. 1962).
In general, women are more sensitive to thermal stimuli and experience greater thermal discomfort related to temperature changes than men (Lautenbacher and Strian, 1991; Golja et al., 2003; Gerrett et al., 2014).

In contrast to this observation, we found that intermittent whole-body cold immersion (water T 14°C) induces similar thermal sensation and comfort perception in both sexes (Solianik et al., 2014).

Subjective perception

Exercising and recovering in T air 8°C

Discharge frequencies at different skin temperatures of thermoreceptors, along with potential transient receptor potential (TRP) channels associated with receptor function (Craig, 2002; Vay et al., 2012; Tansey & Johnson, 2015).

Brief Rewarming Blunts Hypothermia-Induced Alterations in Sensation, Motor Drive and Cognition

Marius Brazaitis², Haverillas Paulauskas¹, Albertas Skursysas¹, Henning Buddle¹,²,³, Laura Dzusnevičiute⁴ and Nenius Eimantas¹

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² Faculty of Human Sciences, Medical School Hamburg, Hamburg, Germany
³ Sports Science Department, Reynolds University, Reykjavik, Iceland
⁴ Faculty of Social Sciences, Arts and Humanities, Kaunas University of Technology, Kaunas, Lithuania
Cold acclimation recruits human brown fat and increases non-shivering thermogenesis


Time Course of Physiological and Psychological Responses in Humans during a 20-Day Severe-Cold–Acclimation Programme

Marius Brazaitis1, Nerijus Elmantas1, Laura Daniuseviciute2, Neringa Baranauskienė1, Erika Skrodienė3, Albertas Skuruva3

1 Sports Science and Innovation Institute, Lithuanian Sports University, Kaunas, Lithuania; 2 Department of Educational Studies, Kaunas University of Technology, Kaunas, Lithuania; 3 Department of Laboratory Medicine, Medical Academy, Lithuanian University of Health Sciences, Kaunas, Lithuania
In perspective

As we performed our study during follicular phase, it would be of greater interest to investigate whether luteal phase would induce greater resistance to cold-induced alteration on motor, cognitive, stress and immune response;

...and, it is also of great importance to assess sex-specific post-cooling kinetics of stress and proinflammatory markers;

...and, to assess sex-specific response on changes/kinetics in types of cold acclimation during cold-acclimation programme;

...and, to assess sex-specific reactions to cold in α-actinin-3 deficiency genotype.

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laboratory assistant Danutė JUCIENĖ
Prof. Dr. Kazimieras PUKĖNAS

Dr. Nerijus EIMANTAS
Dr. Rima SOLIANIK
Dr. Neringa BARANAUSKIENĖ
Dr. Laura DANIUSEVIČIŪTĖ
Thank you for your attention

Every morning I feel like a mad scientist

Getting the perfect balance of hot and cold water

estonia.ee