Effect of environments on physical performance testing

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EP2 FINLAND

ENVIRONMENTAL EXERCISE PHYSIOLOGY PROGRAM

Heat

Cold

Hypoxia

Individual factors

- Younger age
- Female sex
- Caucasian ethnicity
- Type II fiber predominance

Work constraints

- Intense physical work
- Exercise duration
- Inexperienced personnel
- Air travel within past 24 h
- Unacclimatized personnel
- Geographical region
- Clothing (combat gear)
- Military division

Lifestyle factors

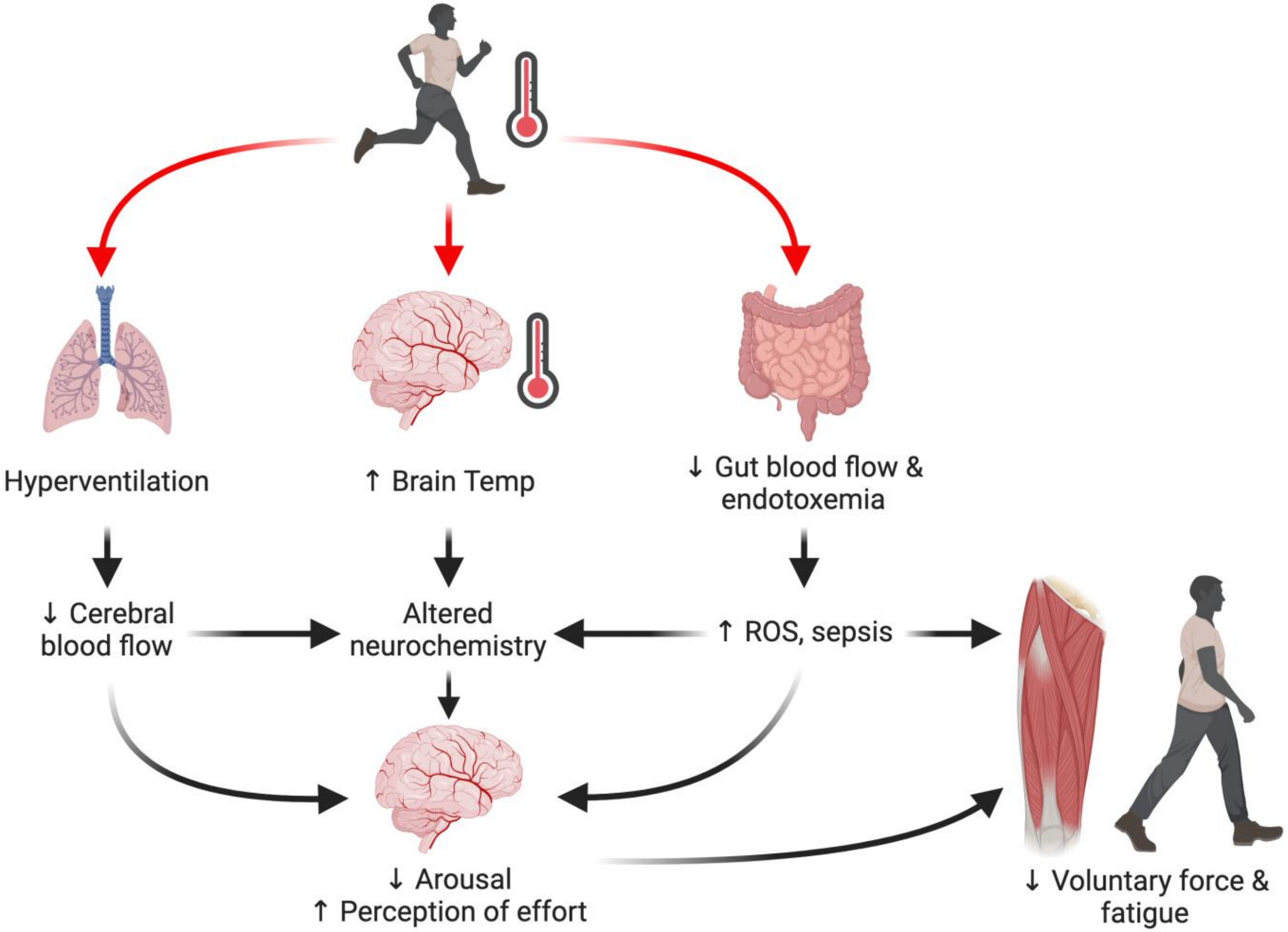
- Individual volition
- Overweight / obesity
- Low Fitness
- Current smoking
- Alcohol intake in past 48 h
- Illicit drugs use
- Supplement use
- Dehydration
- Previous day heat stress
- Lack of sleep
- Poor nutrition (meal skipping in past 24 h)

Health factors

- Previous heat illness
- Vaccination within past 48 h
- Current sunburn
- Burns
- Medication use (e.g. antihistamines, painkillers)
- Sickle cell trait
- Hypohidrosis
- Malignant hyperthermia
- Altered cytokine production
- Sympathectomy
- Mild illness (i.e. Diarrhea, common cold, fever)

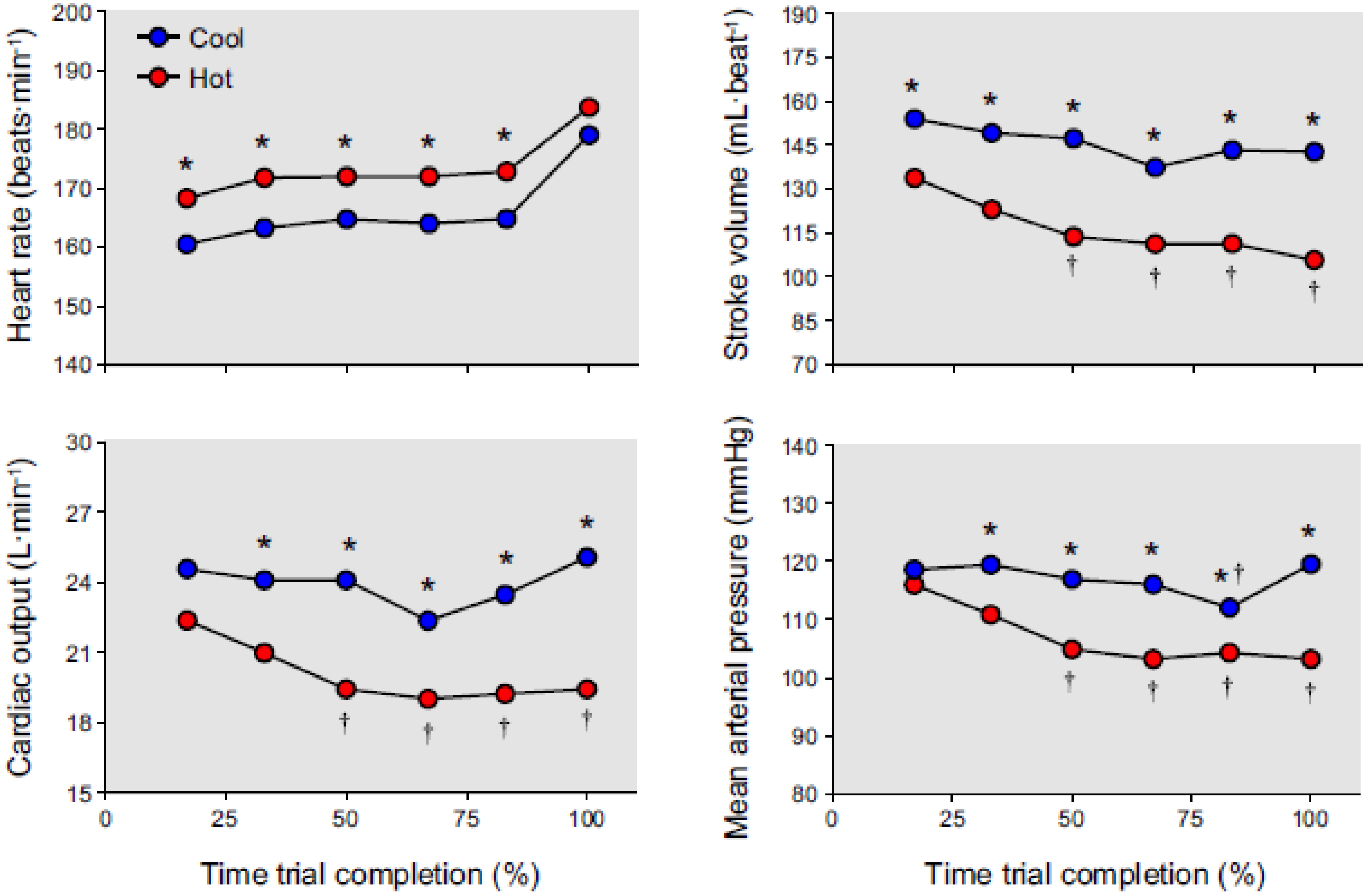
Periard et al. 2021. Adapted with permission from Westwood et al. 2020

Heat



Cheung and Sleivert 2004

Key differences in CV responses under heat stress.



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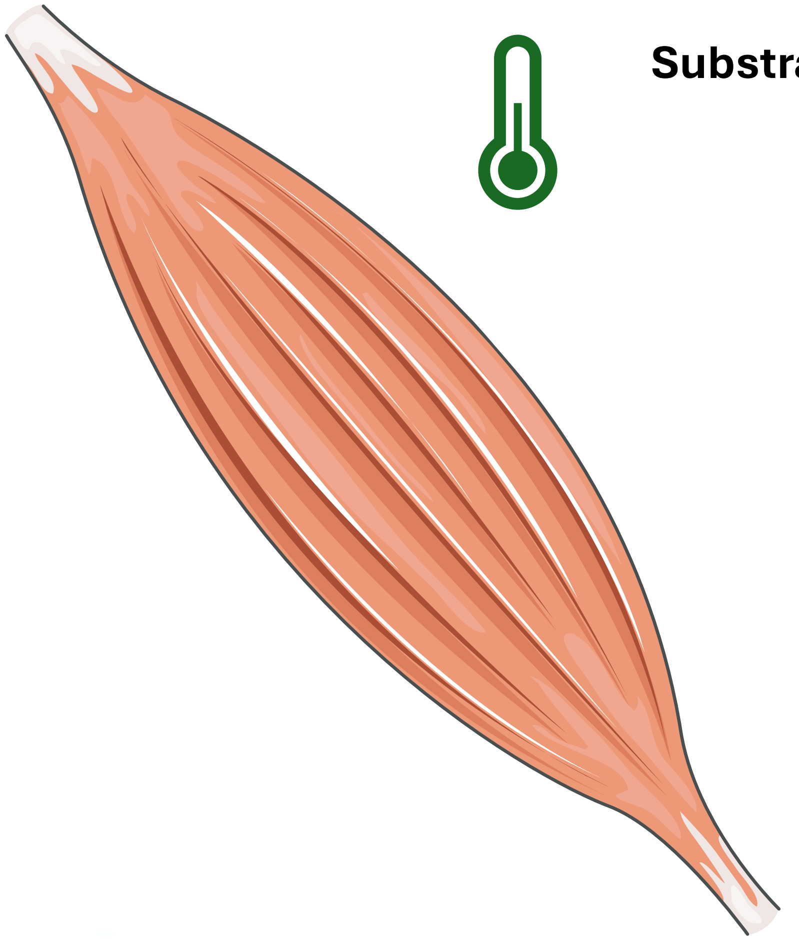
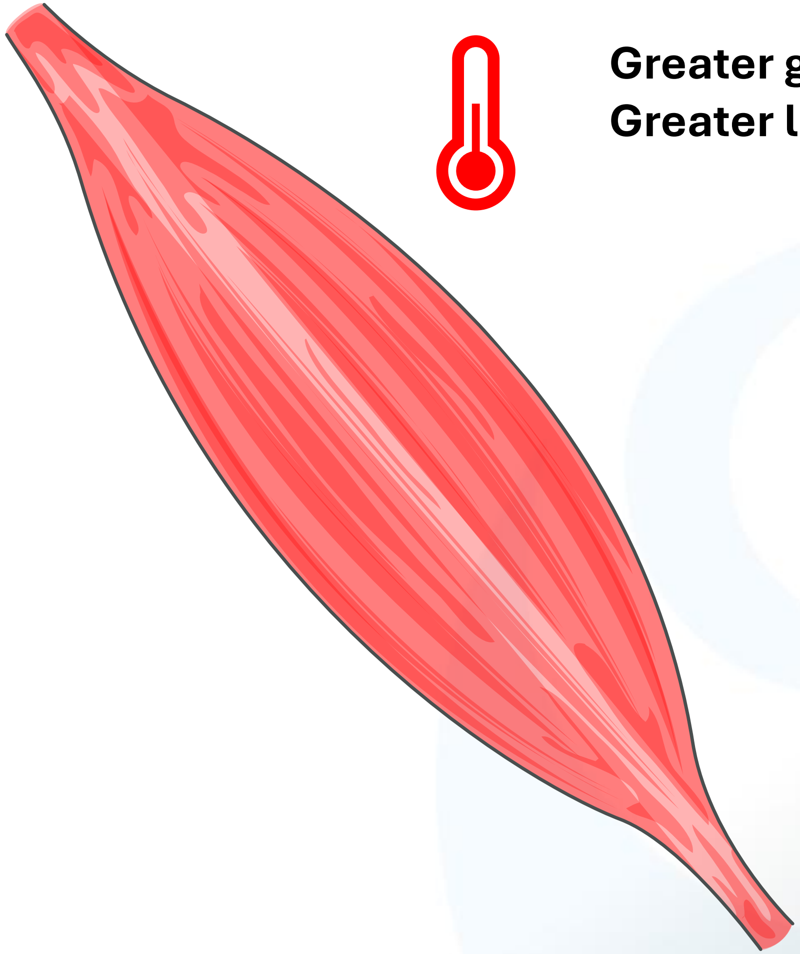
Periard et al. 2021.

Lactate – regulated by muscle temperature

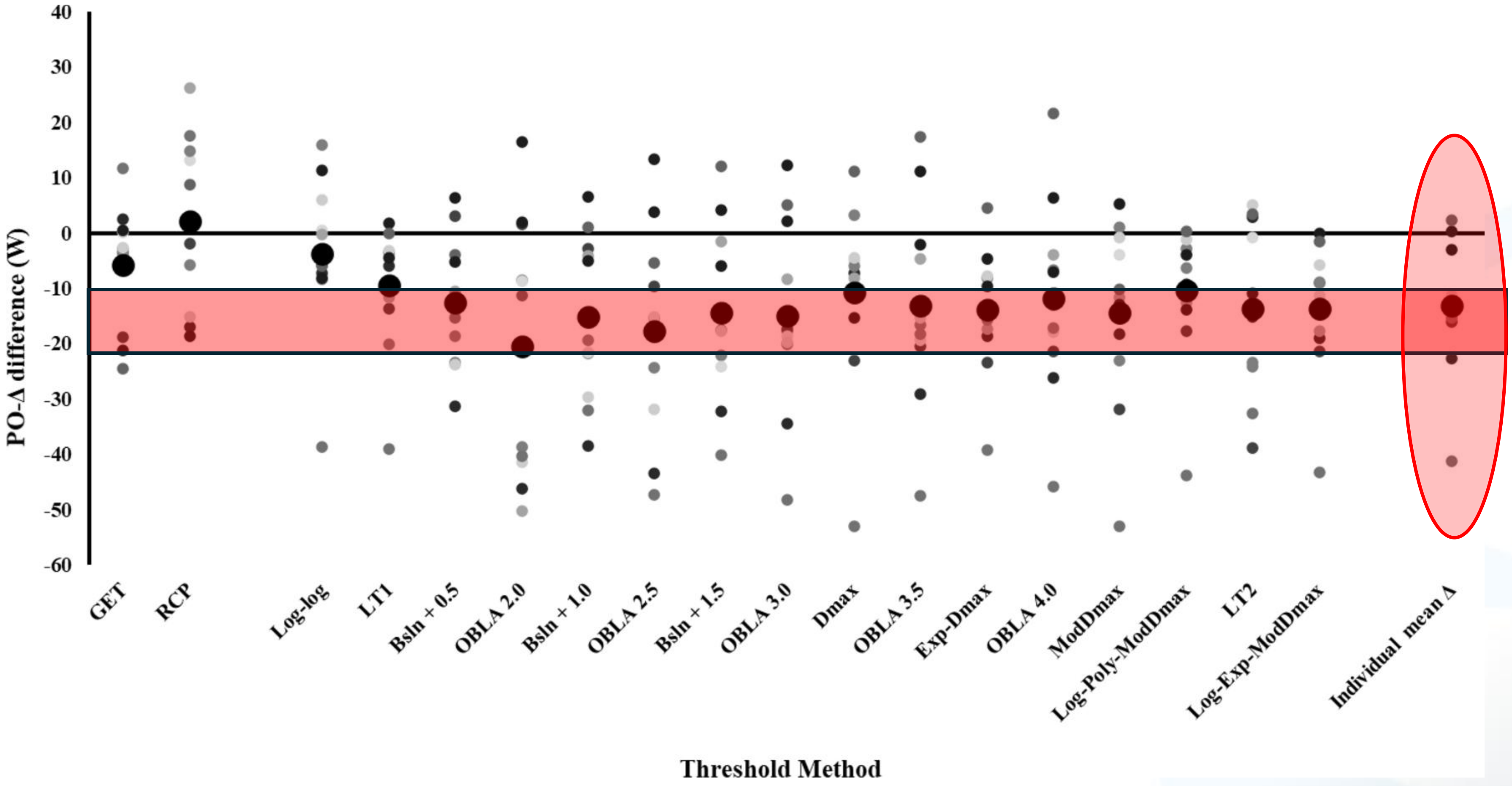


Substrate utilization



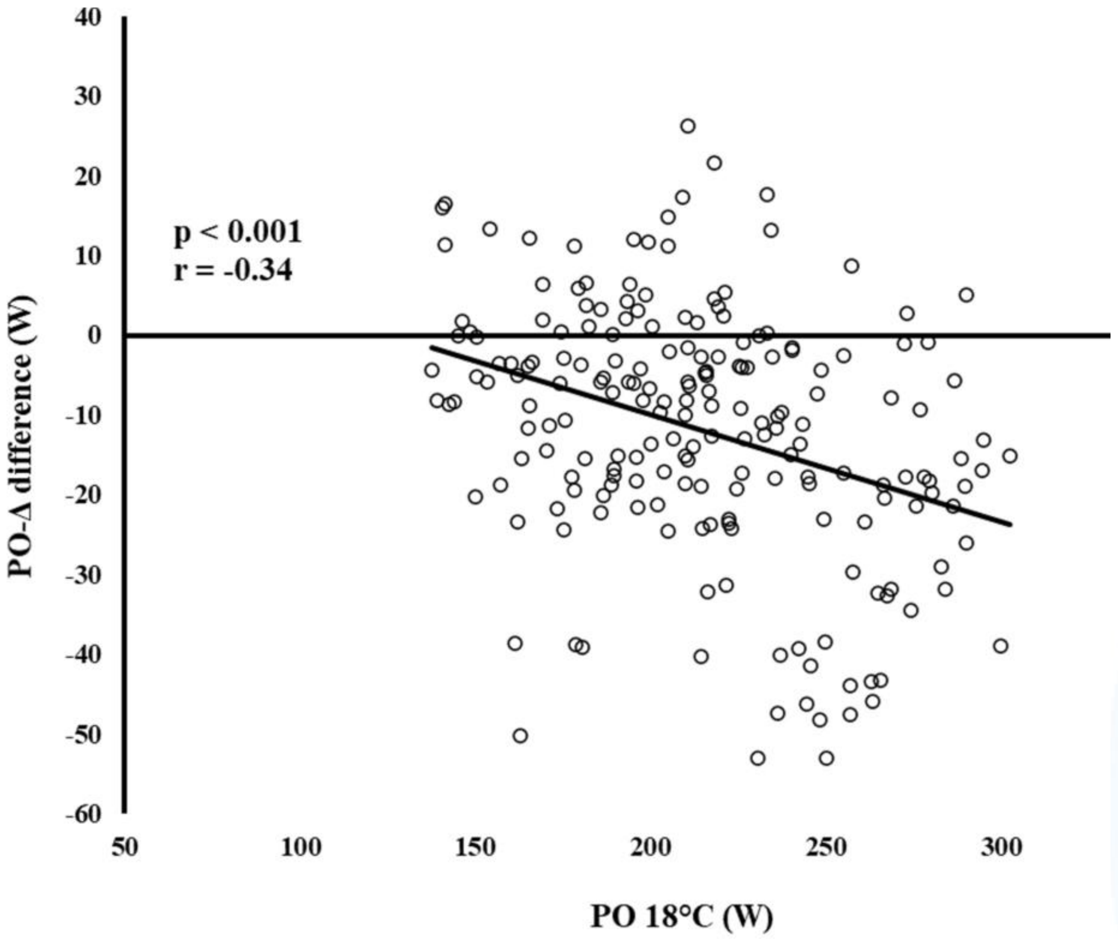
Greater glycogen use
Greater lactate production

Exercise thresholds tend to decrease as ambient air increases



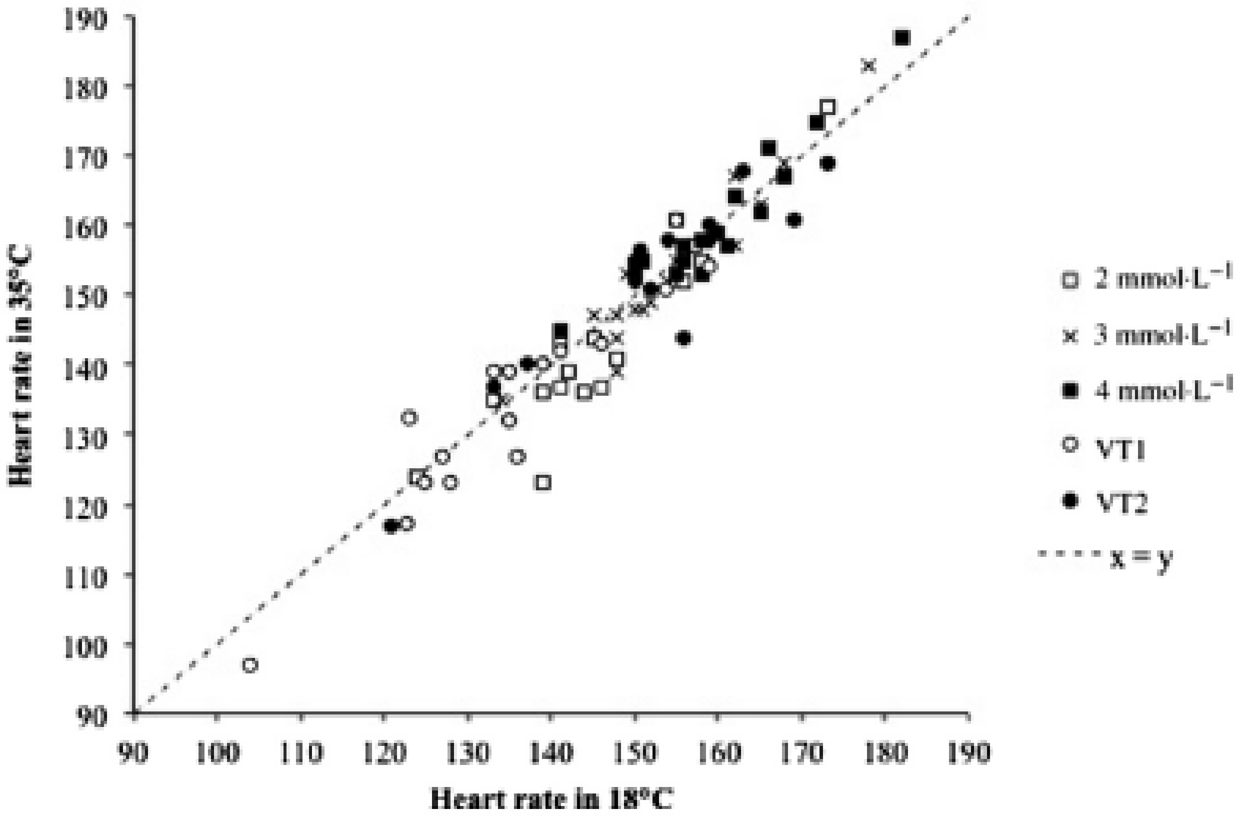
Bourgois et al. 2023

Exercise thresholds tend to decrease as ambient air increases - variability



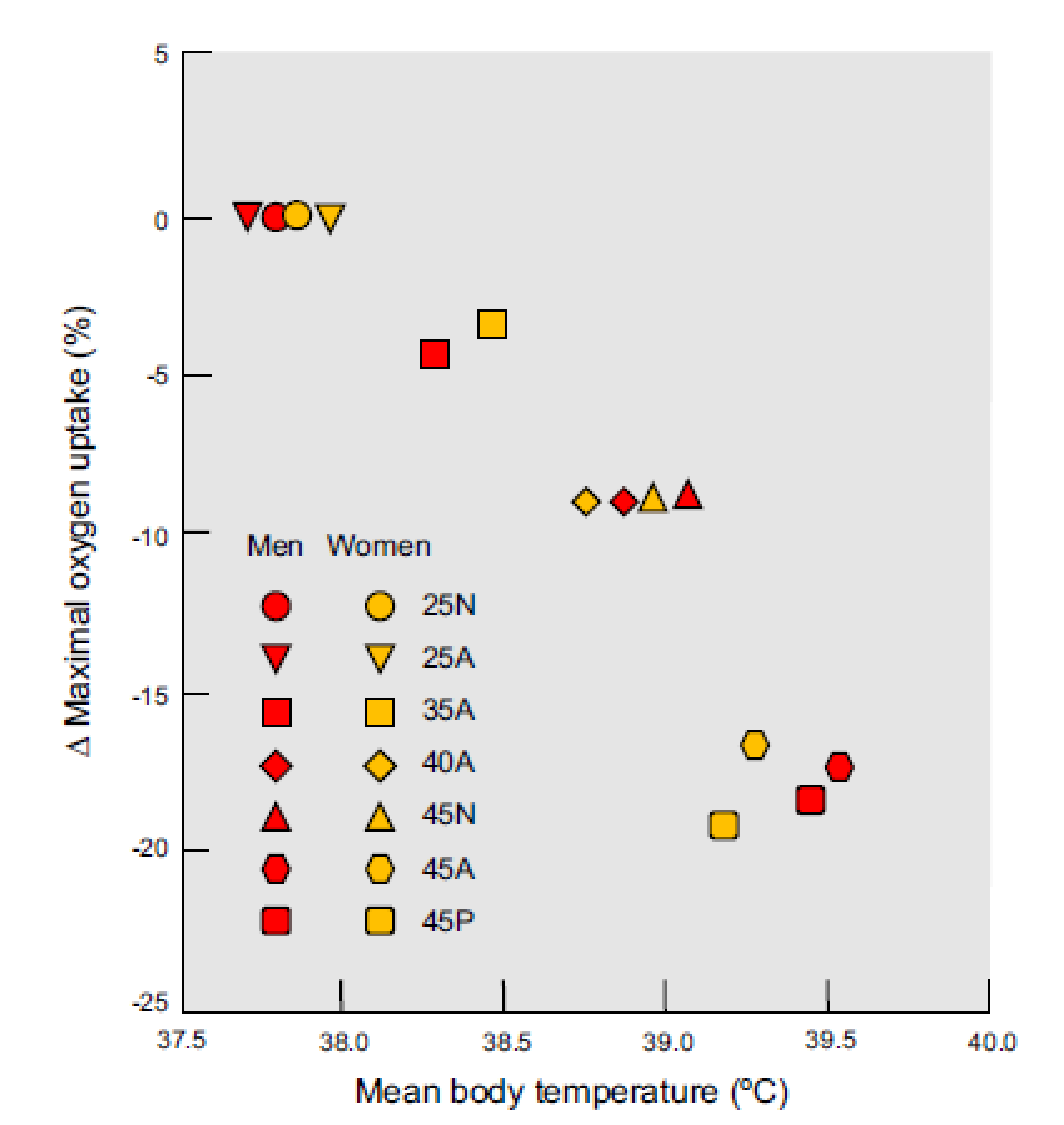
Bourgois et al. 2023

HR measures are the same in hot or temperate environments at matched blood lactate concentration

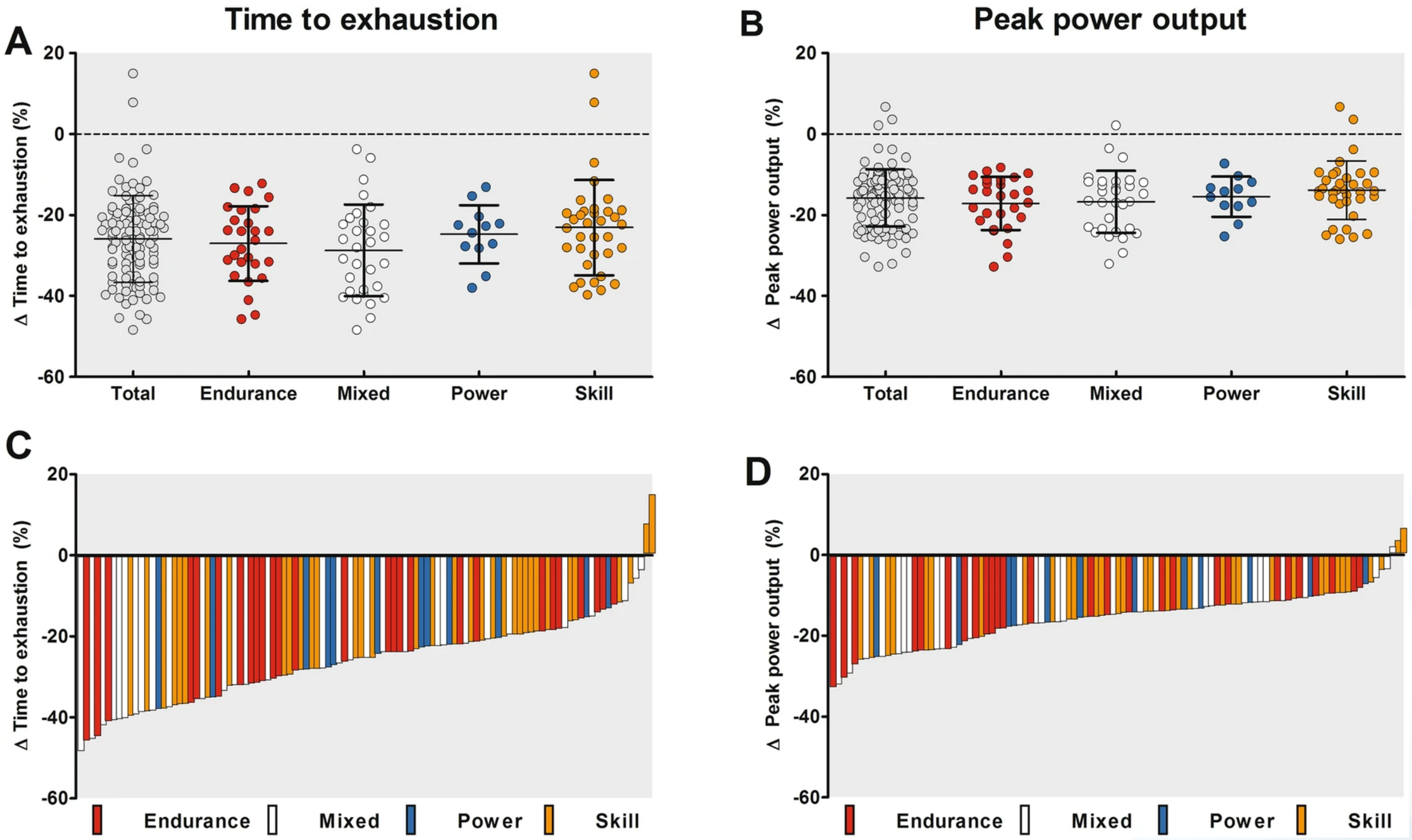


Maunder et al. 2021

VO_{2max} decreases as heat increases

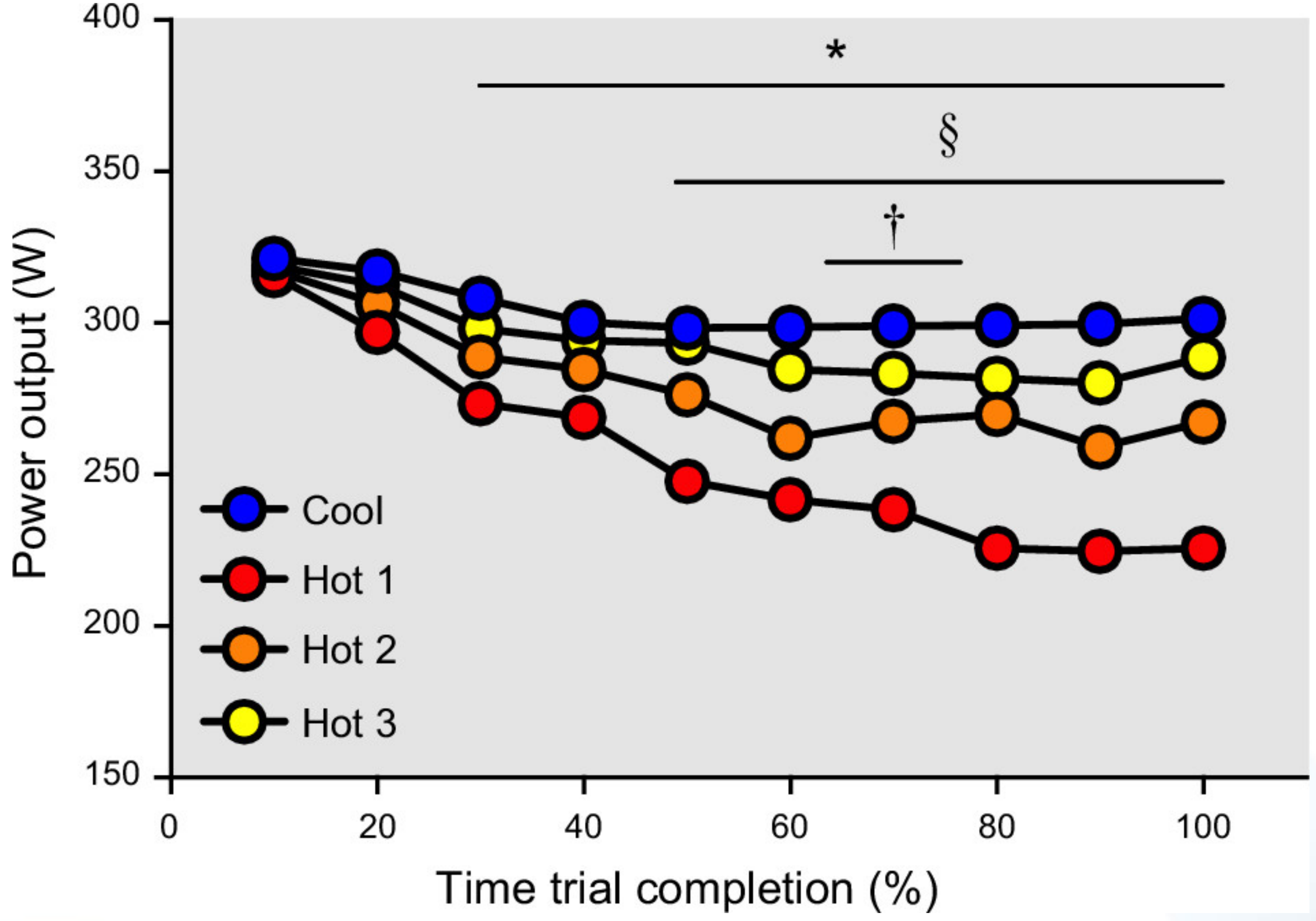


Tokyo-simulated performance relative to control conditions in mixed athletes. TTE -26±11% and PPO -16±7%.



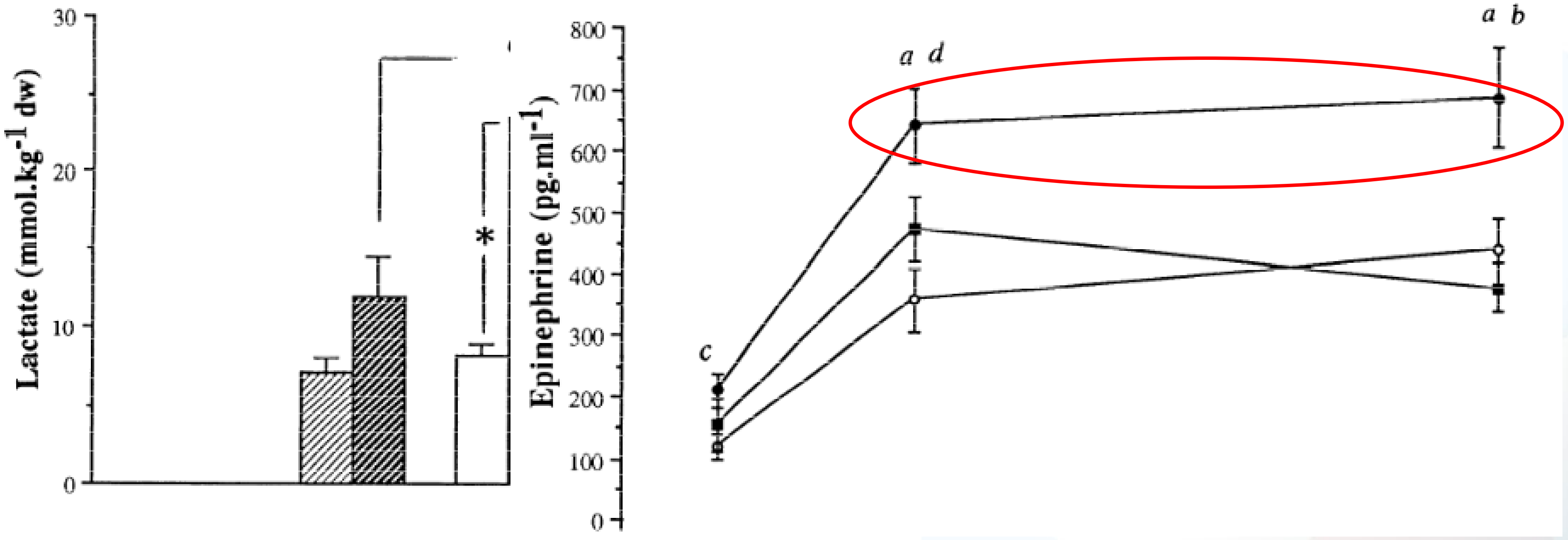
(De Korte et al. 2021)

Following heat acclimation, physical performance and some exercise thresholds return close to normal.



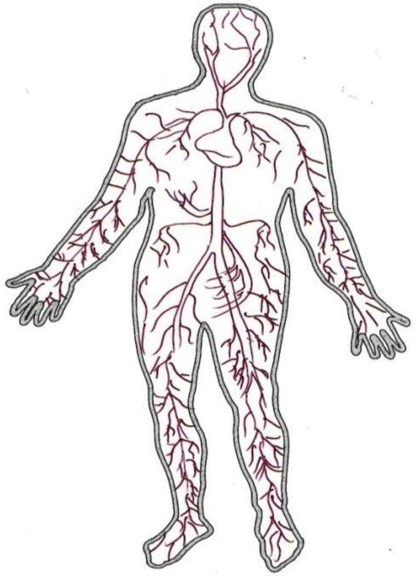
Periard et al. 2021. Redrawn with permission from Racinais et al.

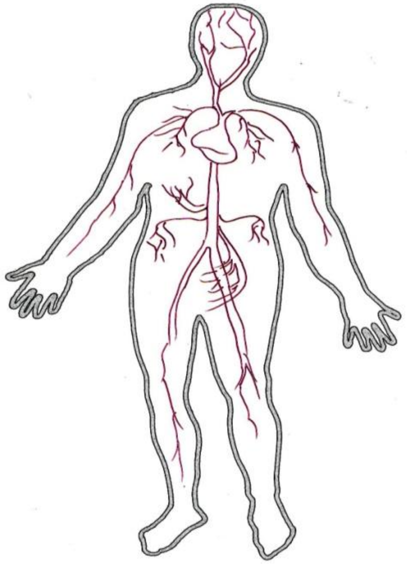
Lactate concentrations before and after exercise and acclimation under heat stress



Febbraio et al. 1994

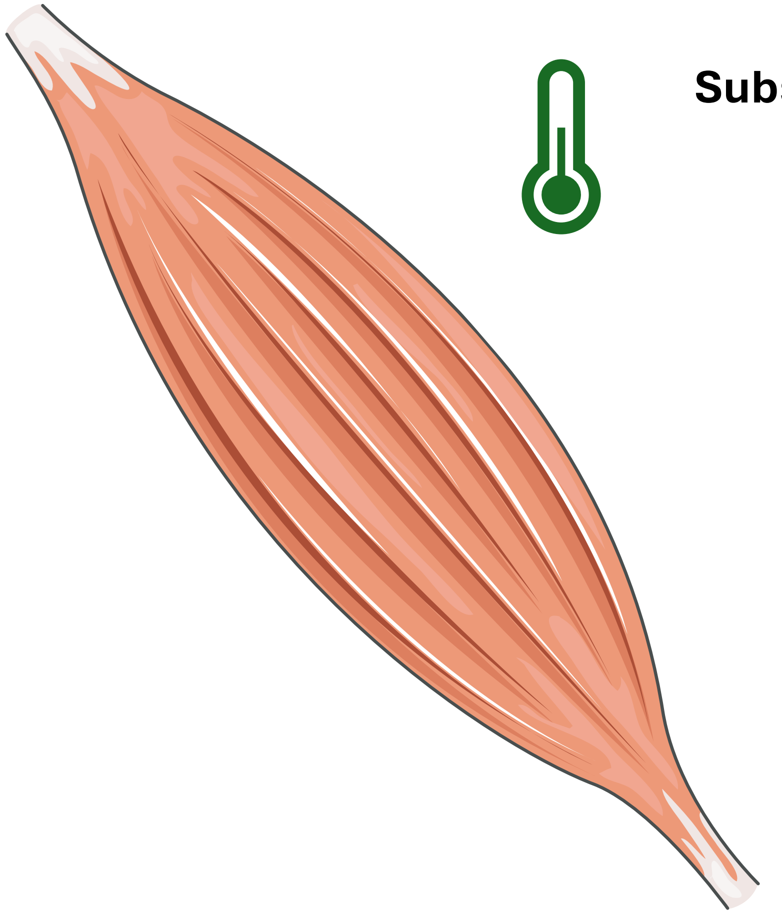
Cold



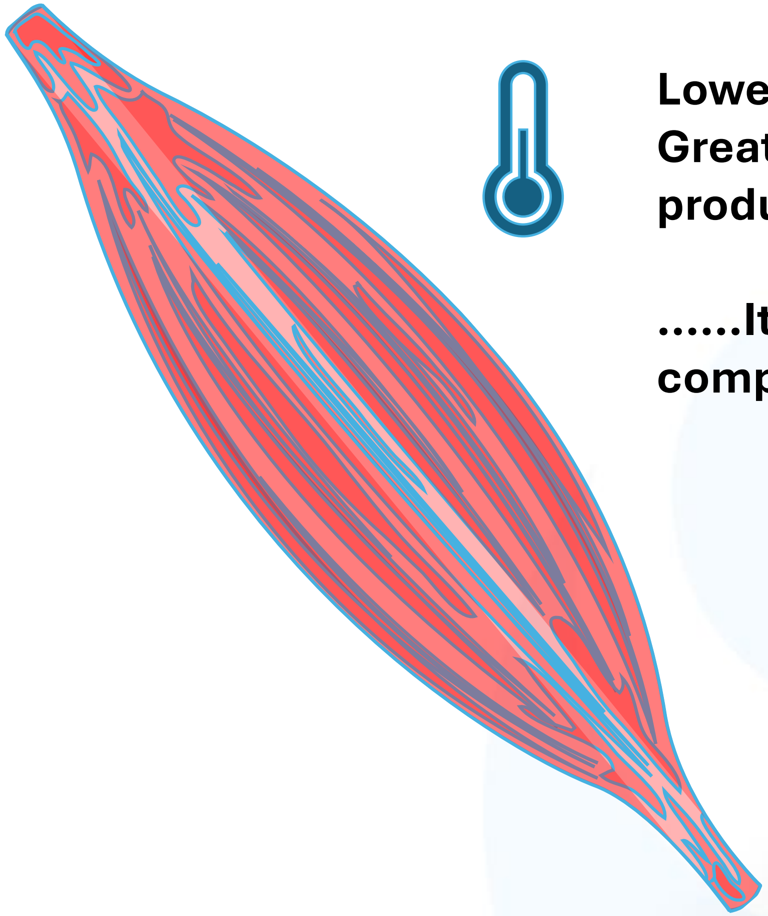


- Vasoconstriction - Lower O_2 Supply (Gonzalez Alonso et al. 2009)
- Lower tissue oxygenation (Gagnon et al. 2017, 2020; Ferguson et al. 2018)
- Lower oxidative reactions (Benett 1985; Sidell et al. 1998)
- Higher O_2 demand at fixed workload (Ferretti 1992, Oksa et al. 2002)

Lactate – regulated by muscle temperature

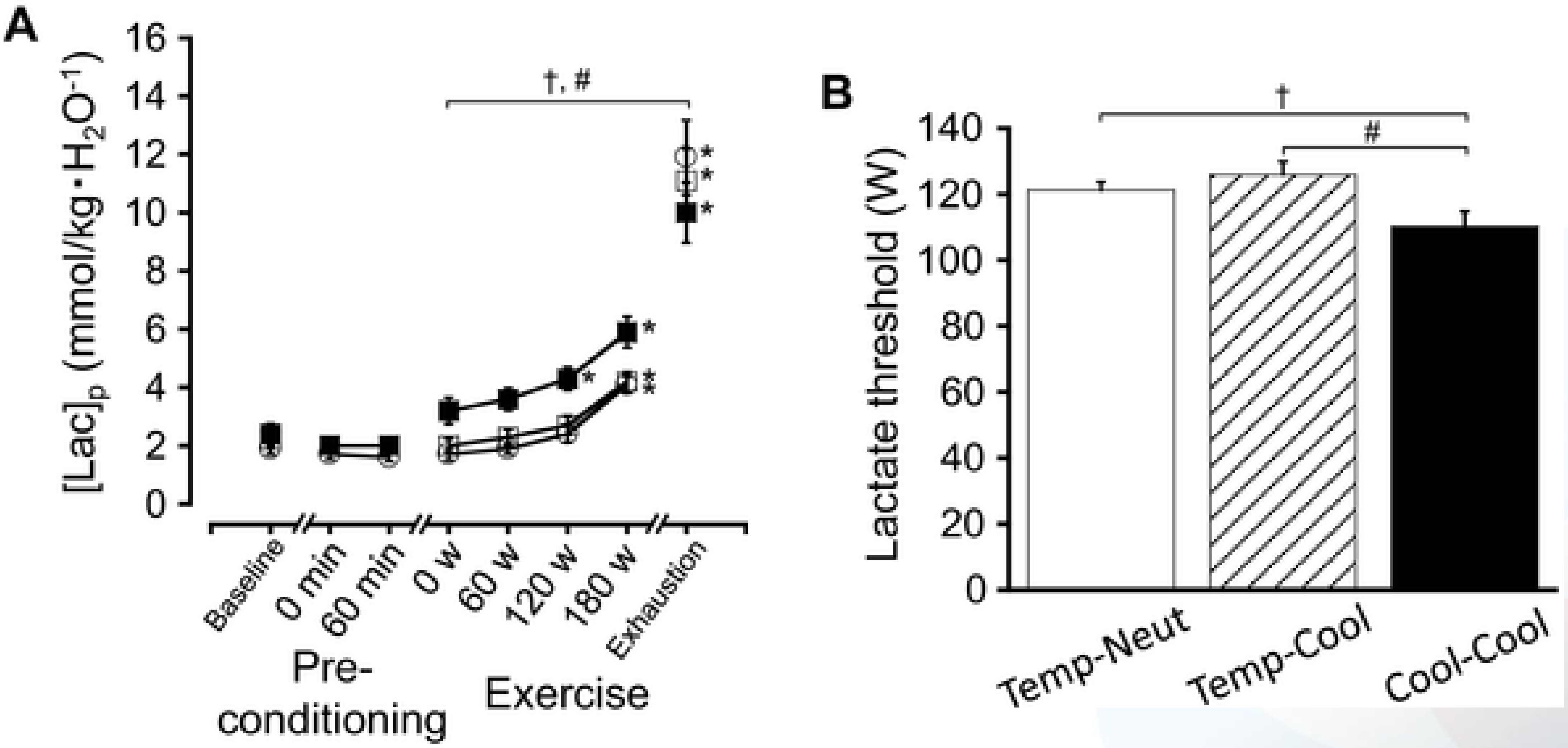


Substrate utilization



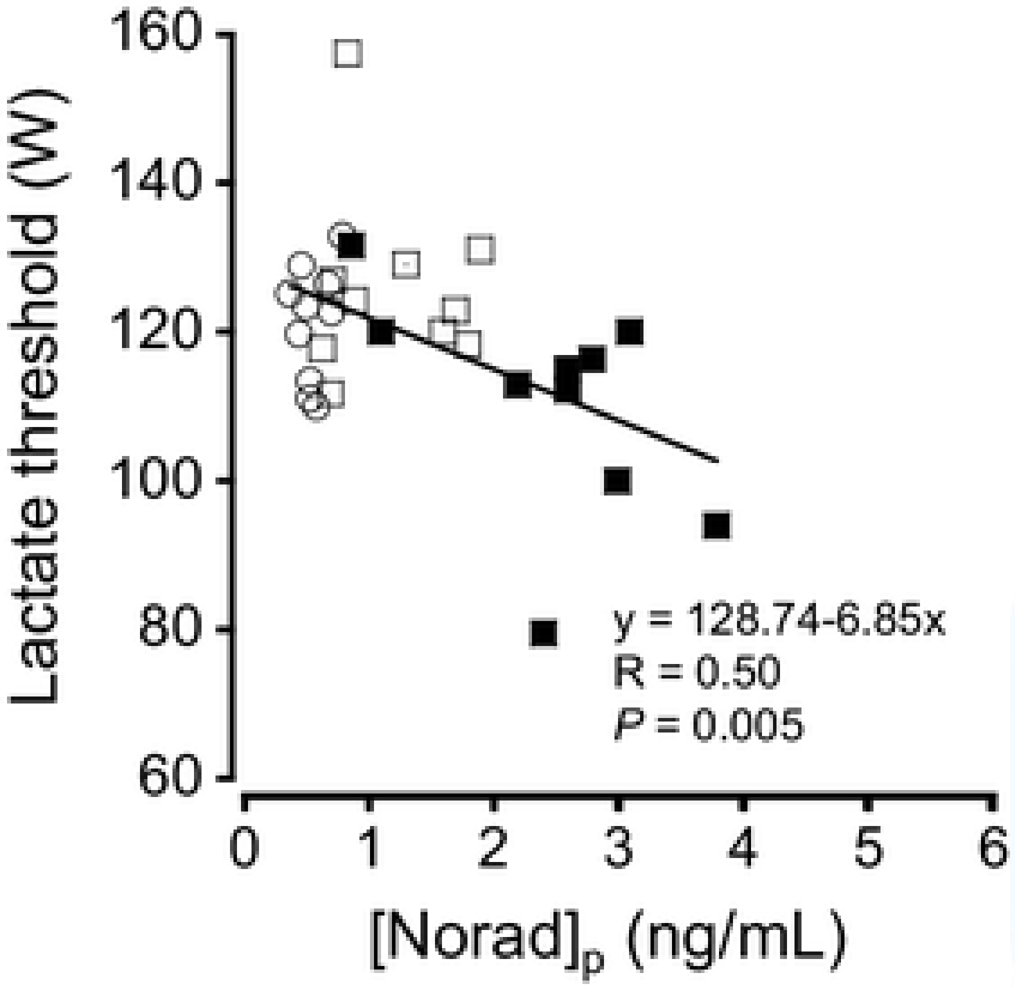
Lower or glycogen use?
Greater or lower lactate production?

......It's more complicated!



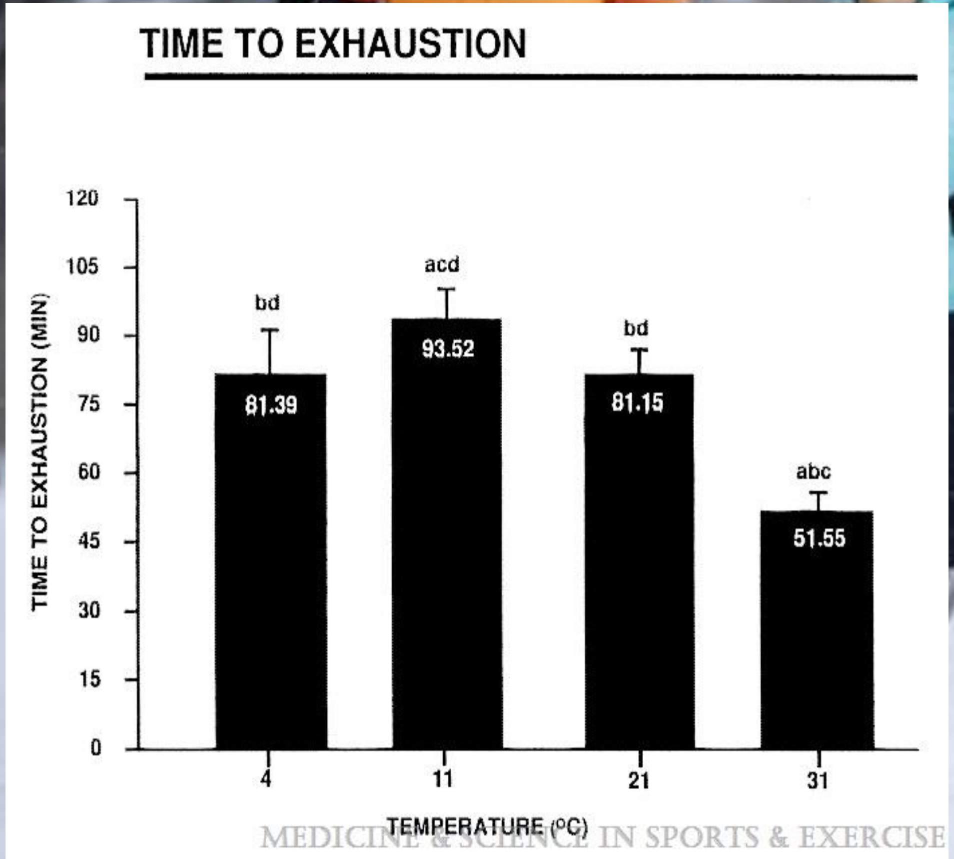
Imai et al. 2018

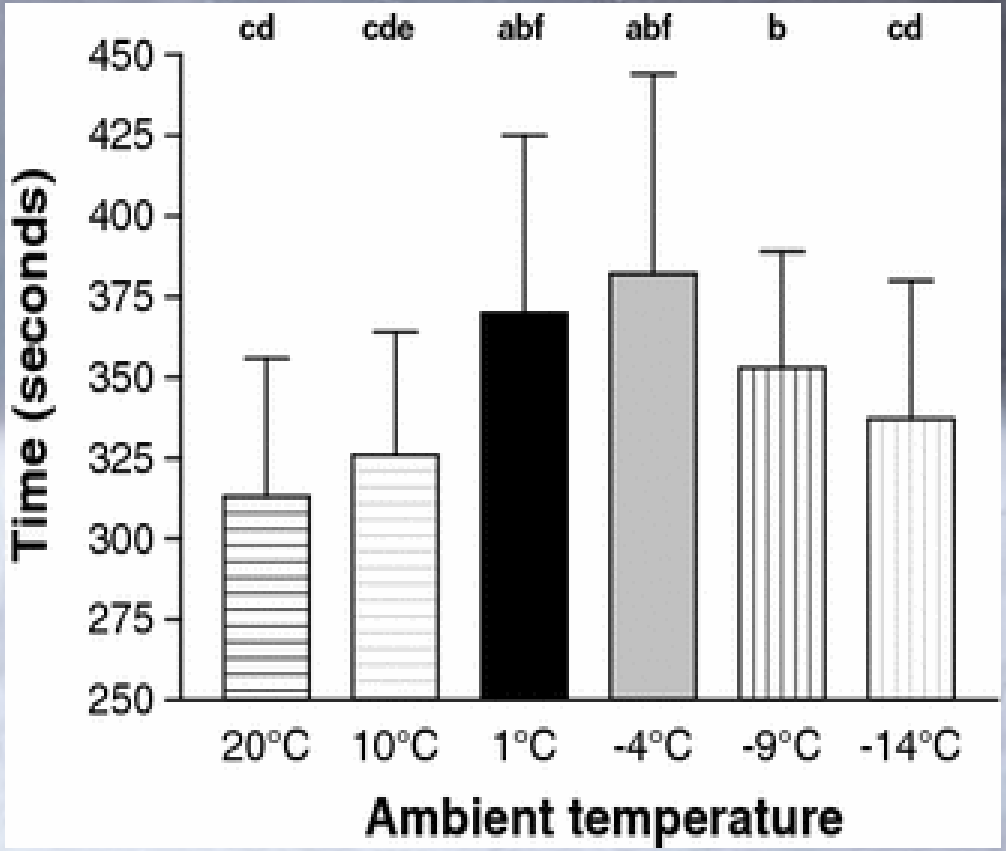
Lactate and catecholamines concentrations are still closely related under cold stress.



Imai et al. 2018

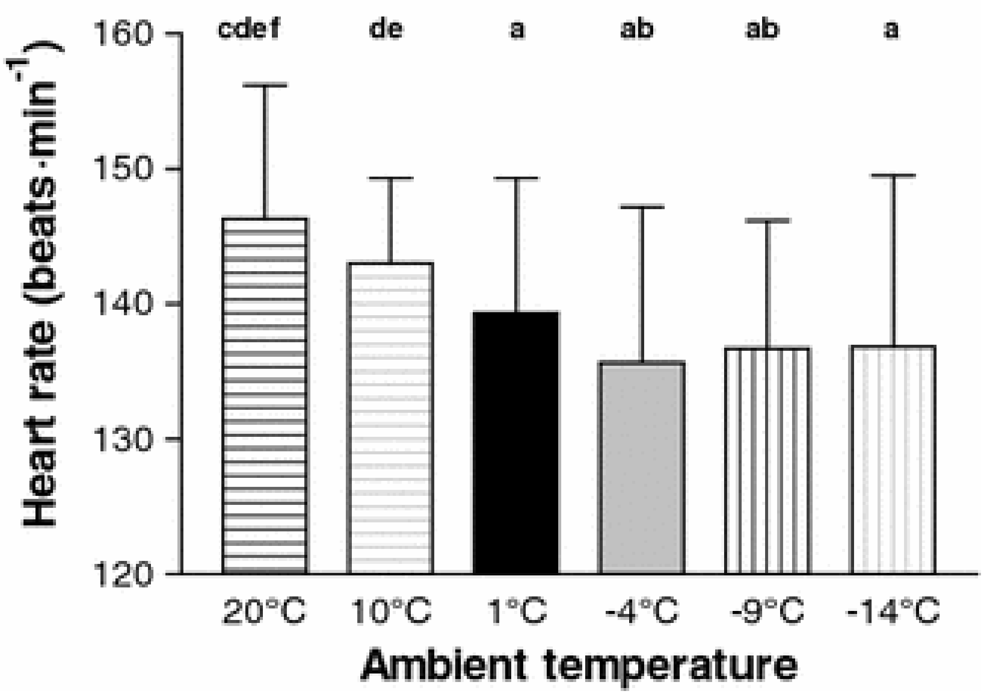
Reverse U-shape relationship

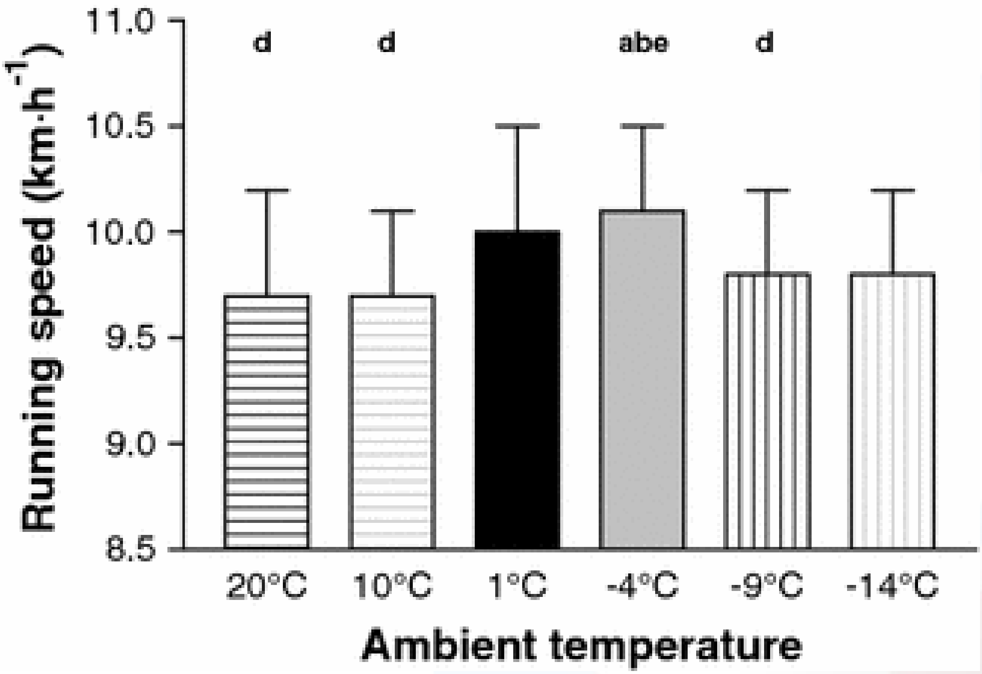




Galloway and Maughan 1997; Sandsund et al. 2012

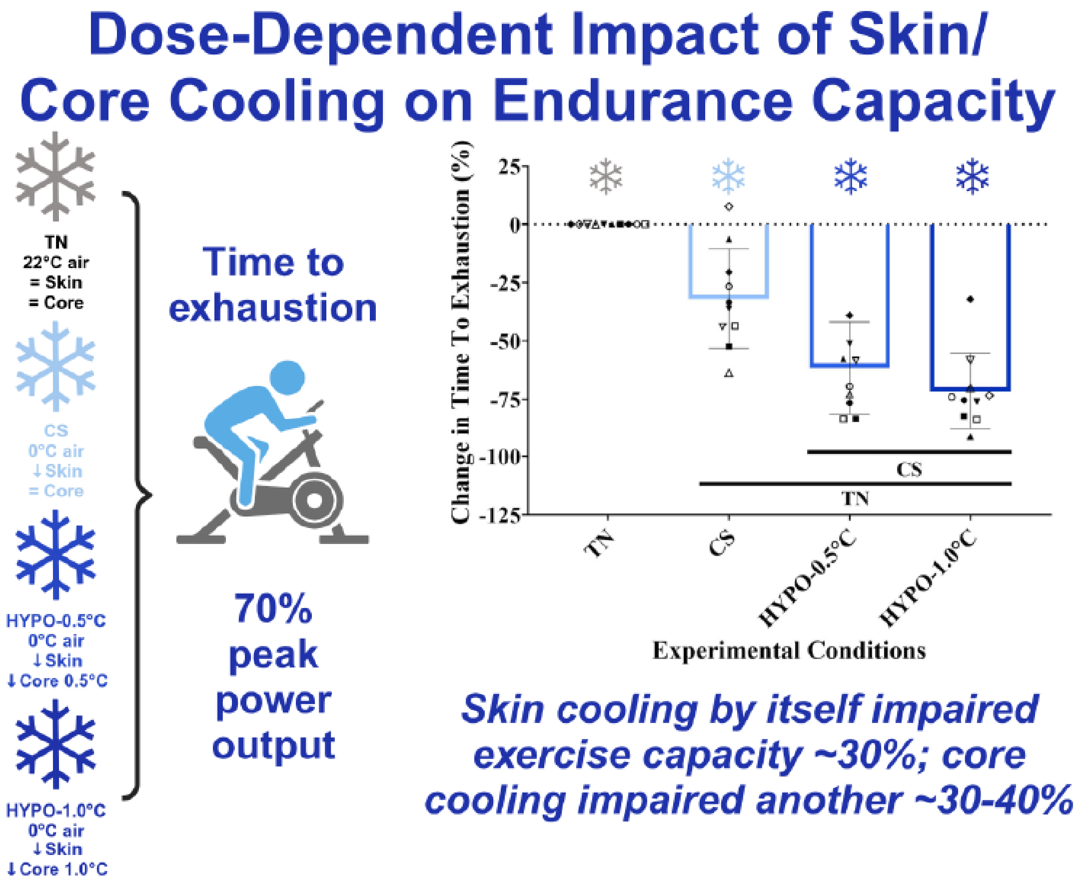
Performance in the cold explained by VO2 and speed





Sandsund et al. 2012

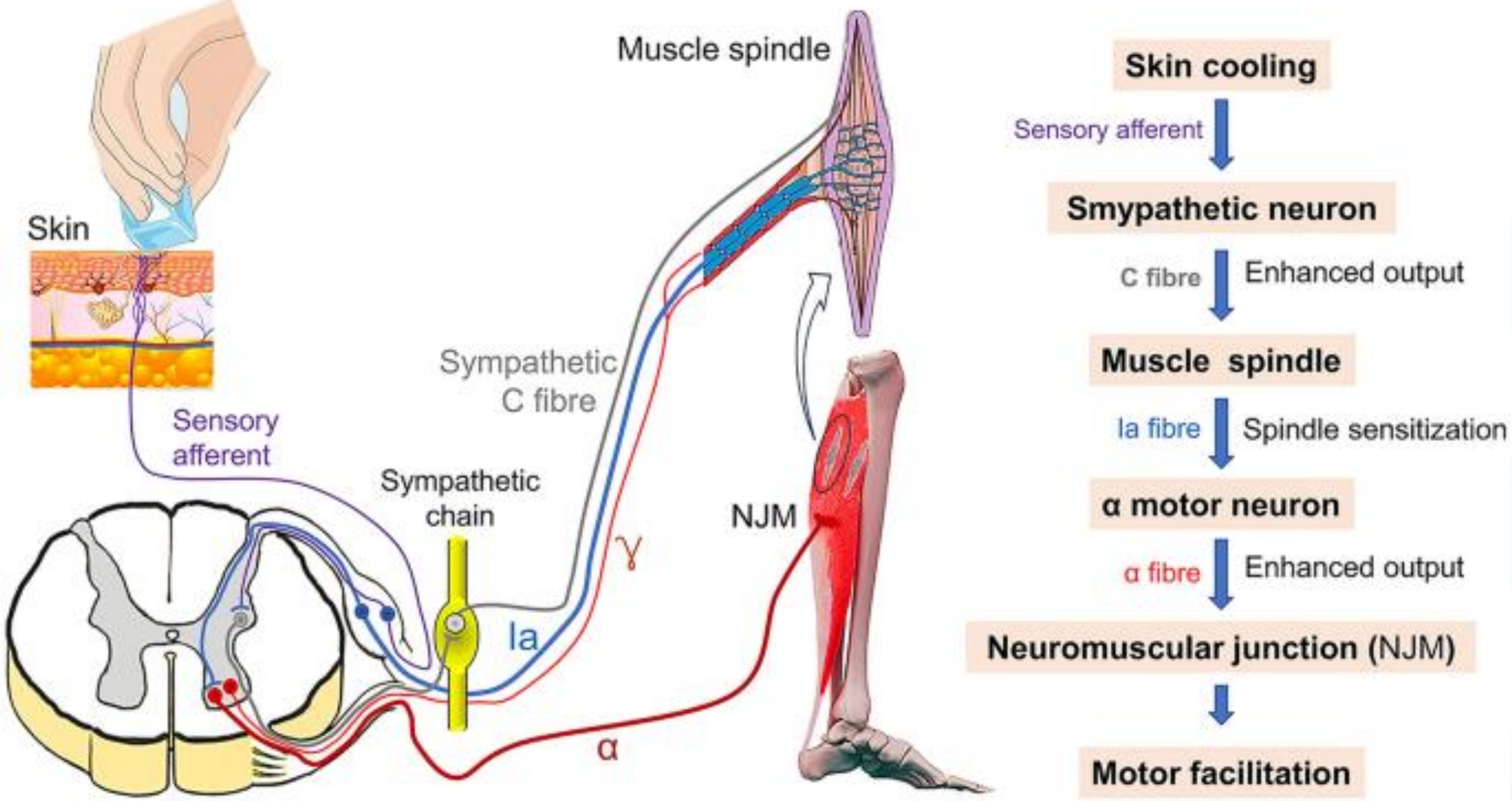
Individual-based design with a dose-dependent skin and core cooling on endurance capacity



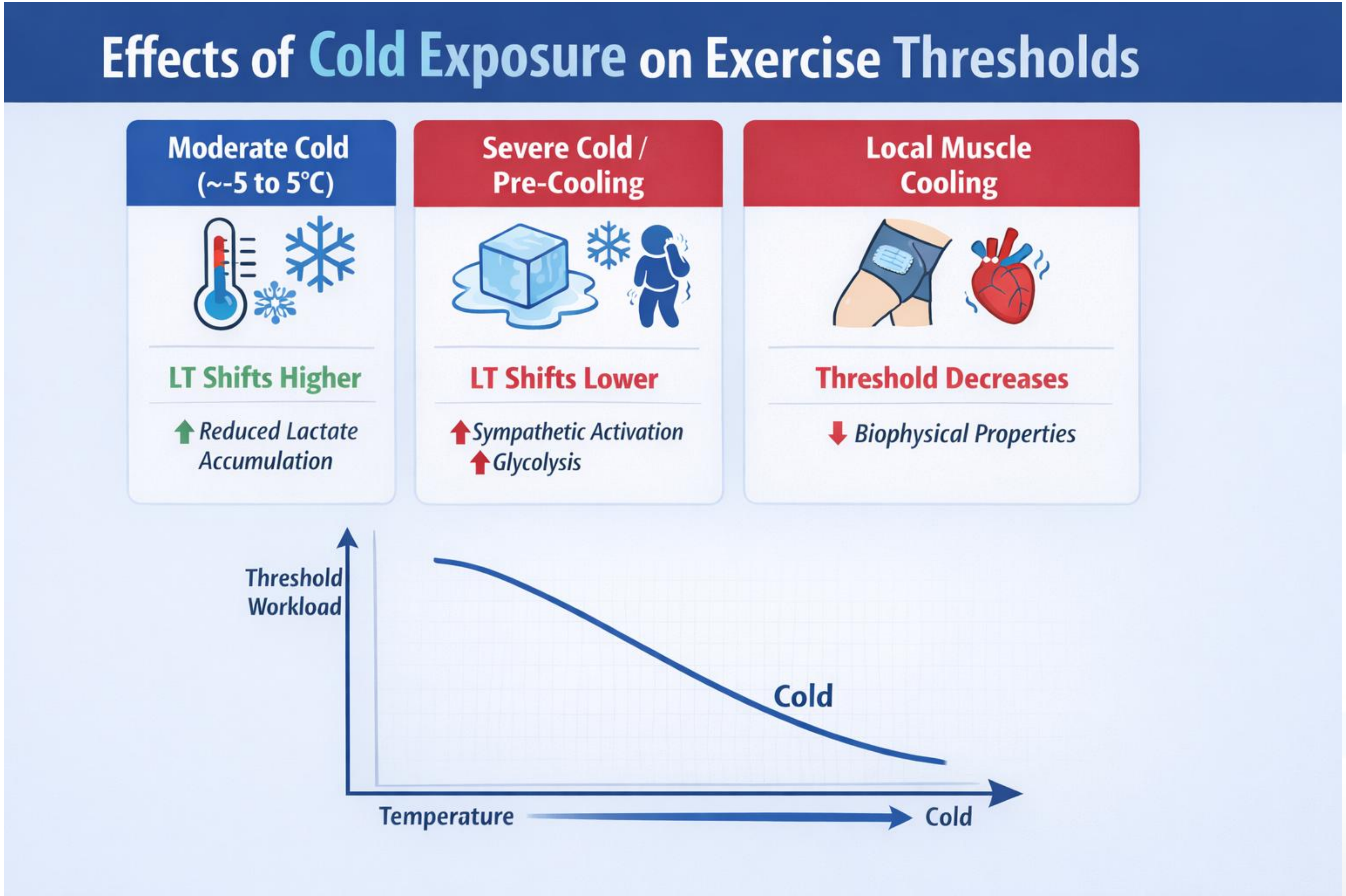
__WALLACE ET AL. 2024__. __TN__, THERMONEUTRAL; __CS__, COLD SKIN; __HYPO-0.5 ° C__, LOWER CORE TEMPERATURE BY 0.5 ° C; __HYPO-1.0 ° C__, LOWER CORE TEMPERATURE BY 1.0°C.

Surface skin cooling may enhance motoneuron pathways and force generation

✓ Brief skin cooling improves motor performance by sensitizing muscle spindles

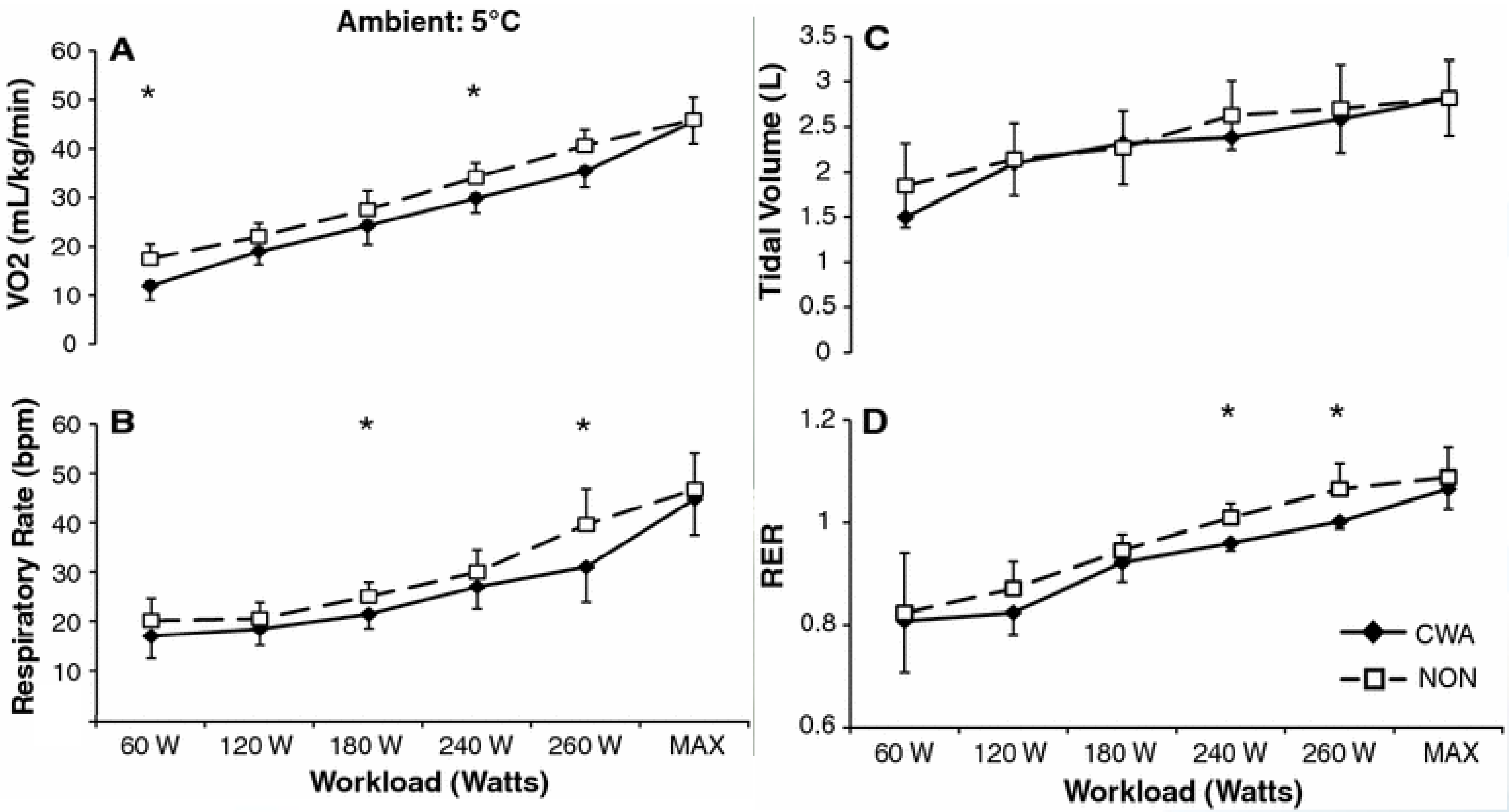


Cetin et al. 2024



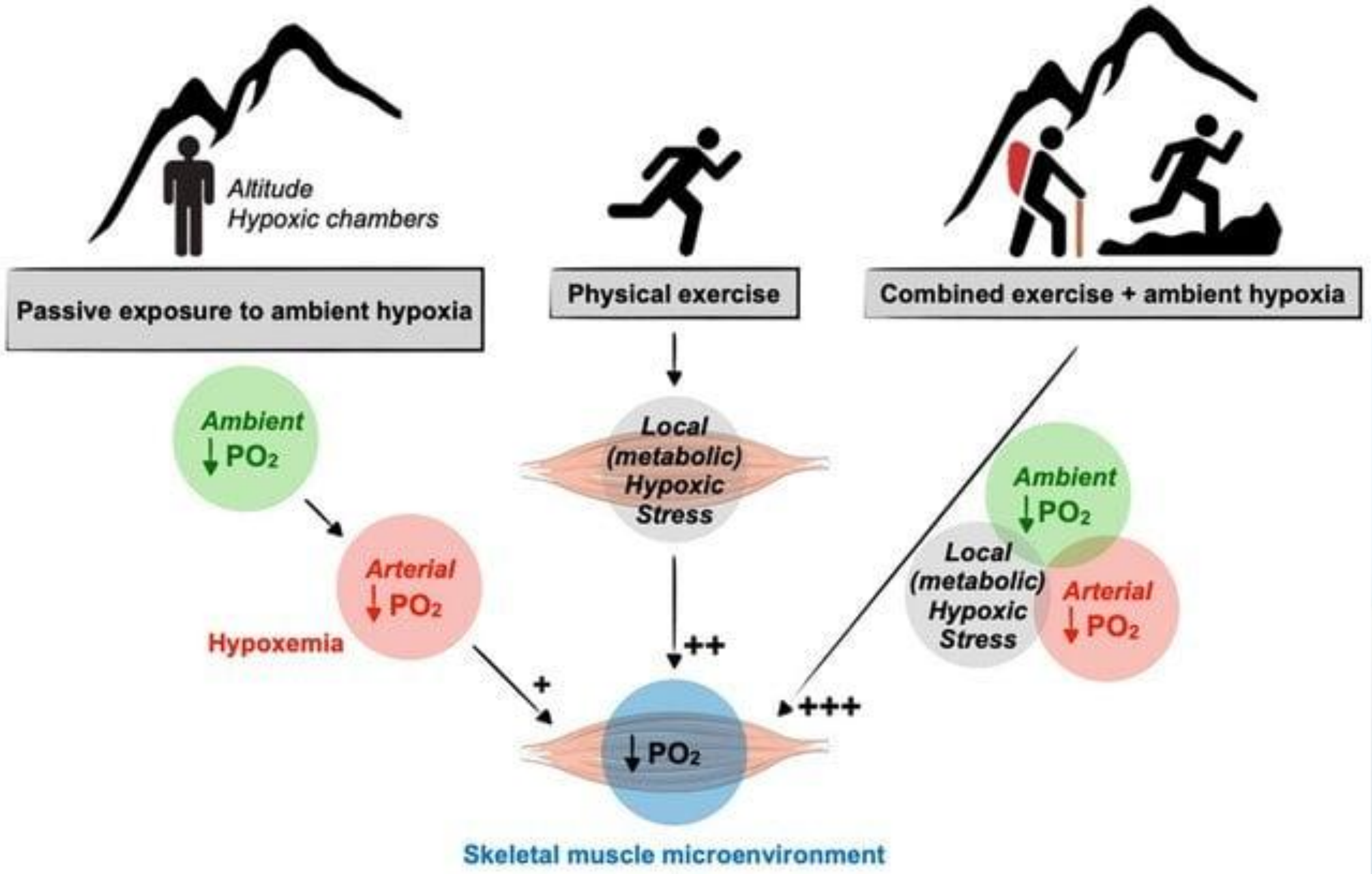
Effects of Cold Exposure on Exercise Thresholds
Moderate Cold (~-5 to 5°C)
LT Shifts Higher
Reduced Lactate Accumulation
Severe Cold / Pre-Cooling
LT Shifts Lower
Sympathetic Activation
Glycolysis
Local Muscle Cooling
Threshold Decreases
Biophysical Properties
Threshold Workload
Cold
Temperature
Cold

Cold Adapation?



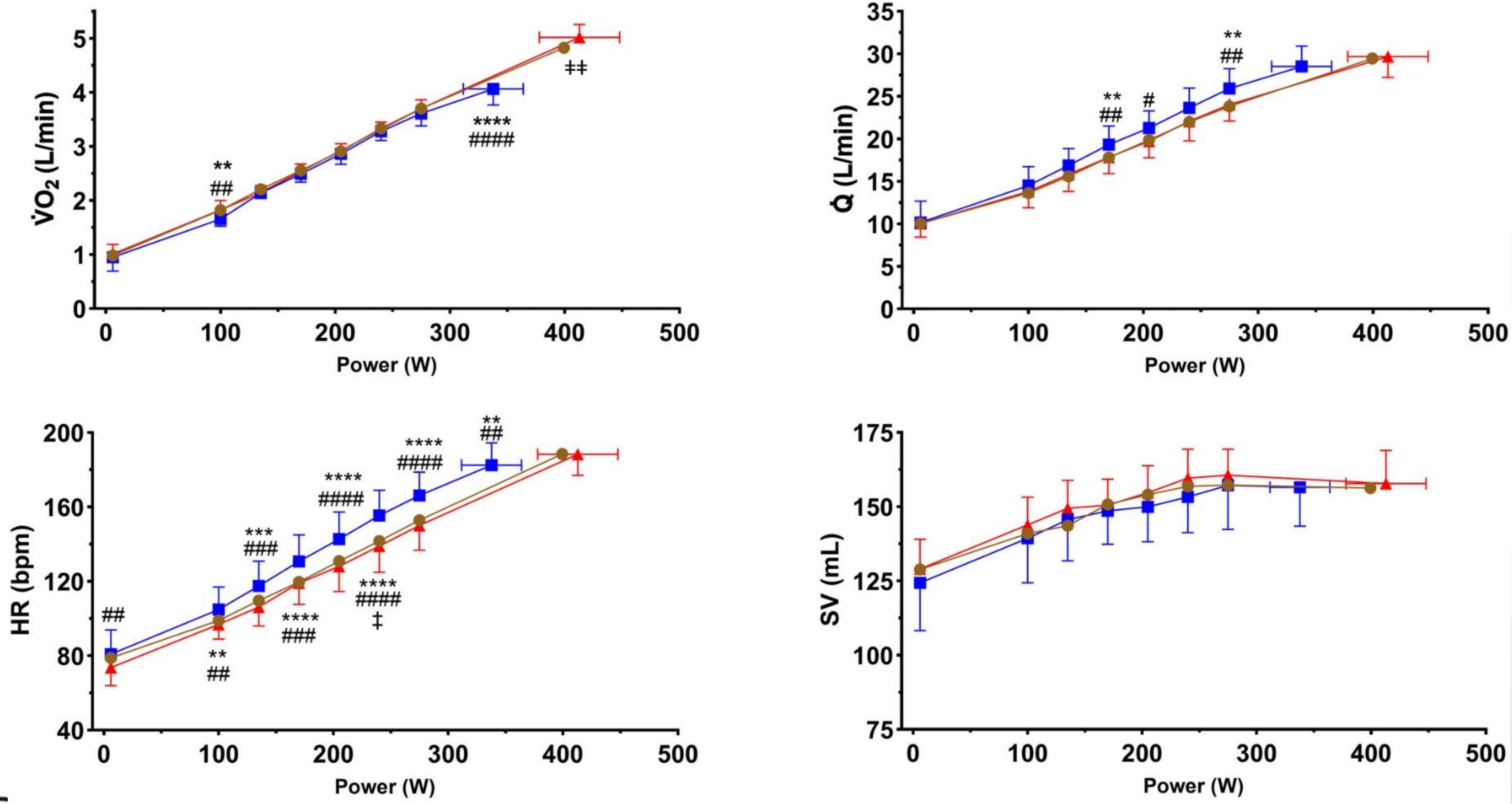
Muller et al. 2012

Hypoxia



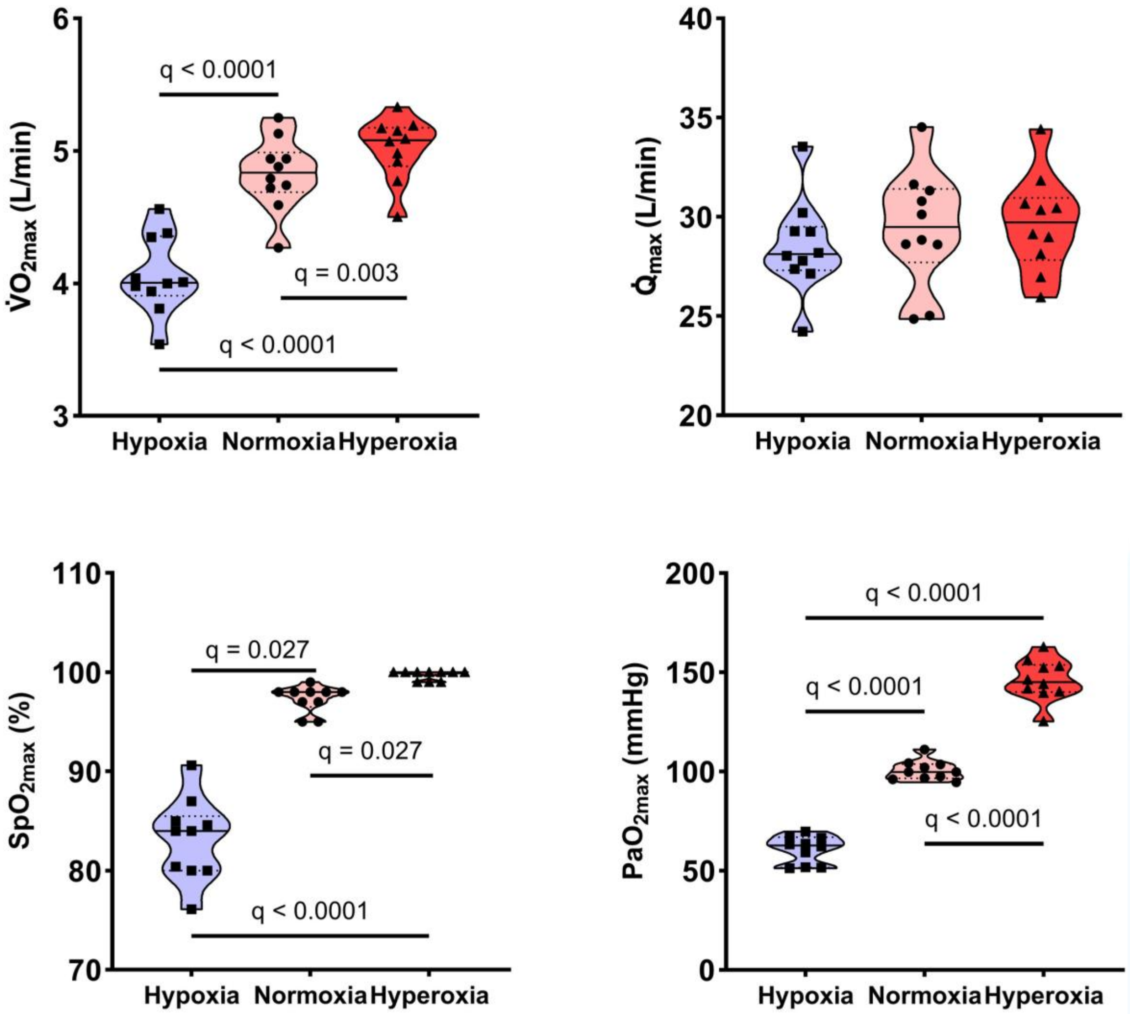
Lemieux and Birot 2021

Submaximal cardiorespiratory values



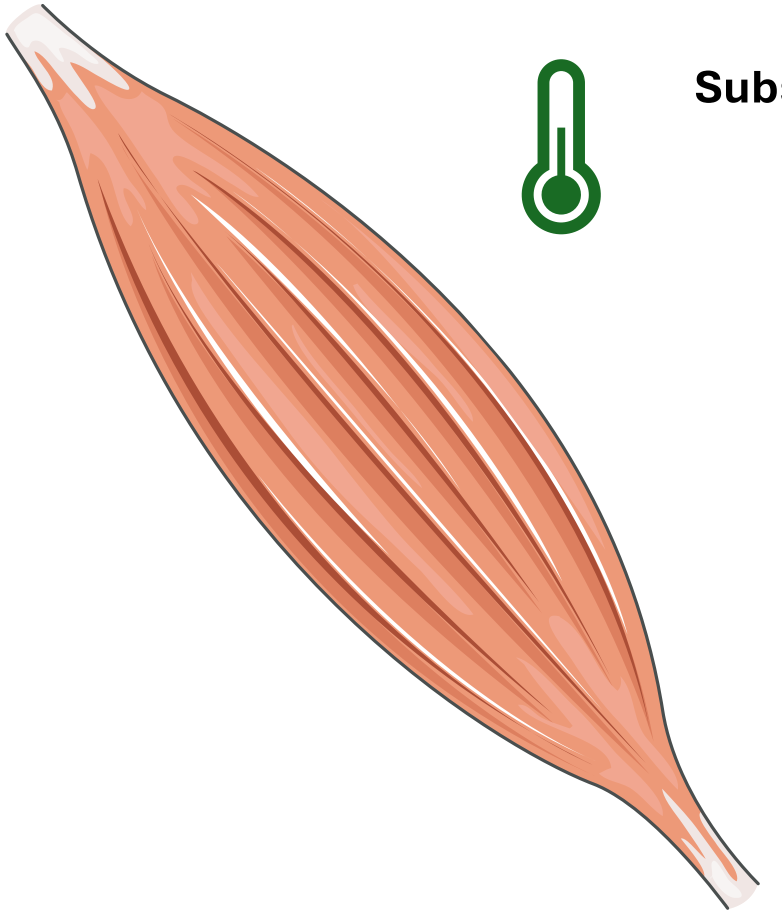
Lehtonen al. 2025

Maximal values

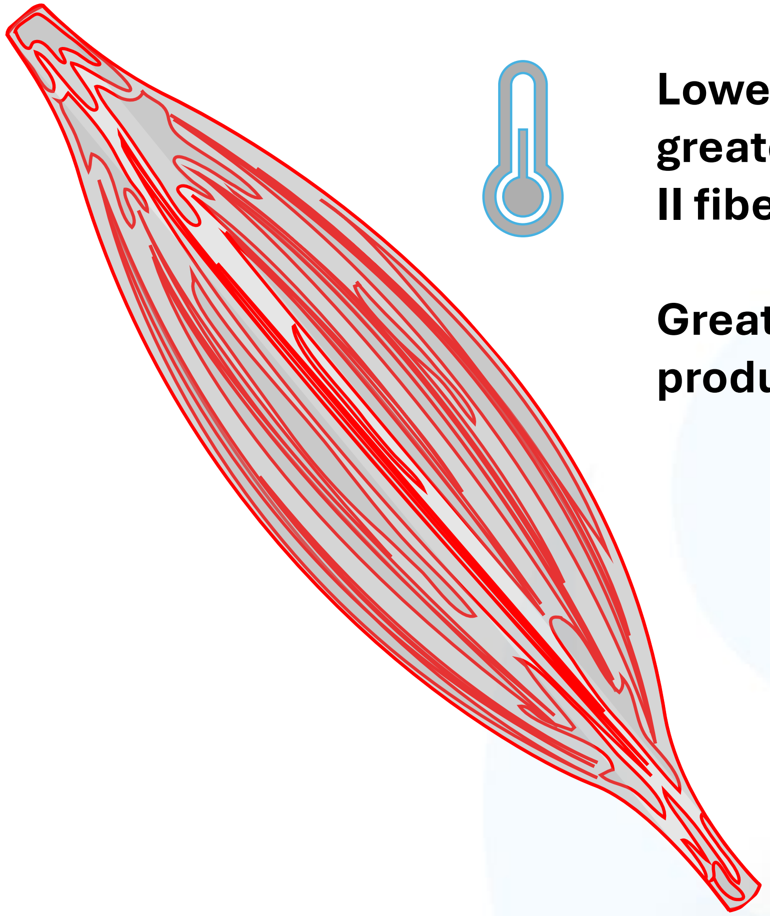


Lehtonen et al. 2025

Lactate – regulated by hypoxia



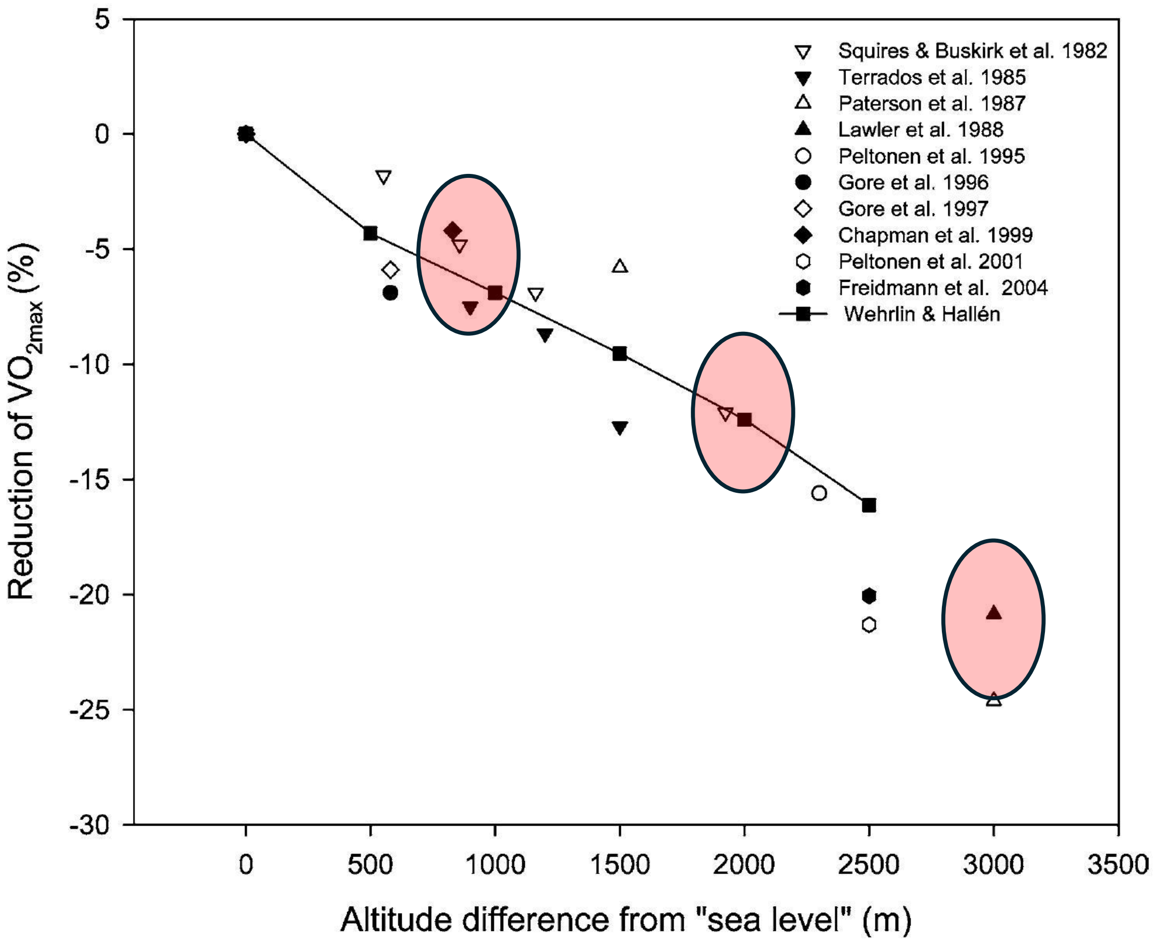
Substrate utilization



Lower O_2 availability and greater reliance on type II fibers

Greater lactate production

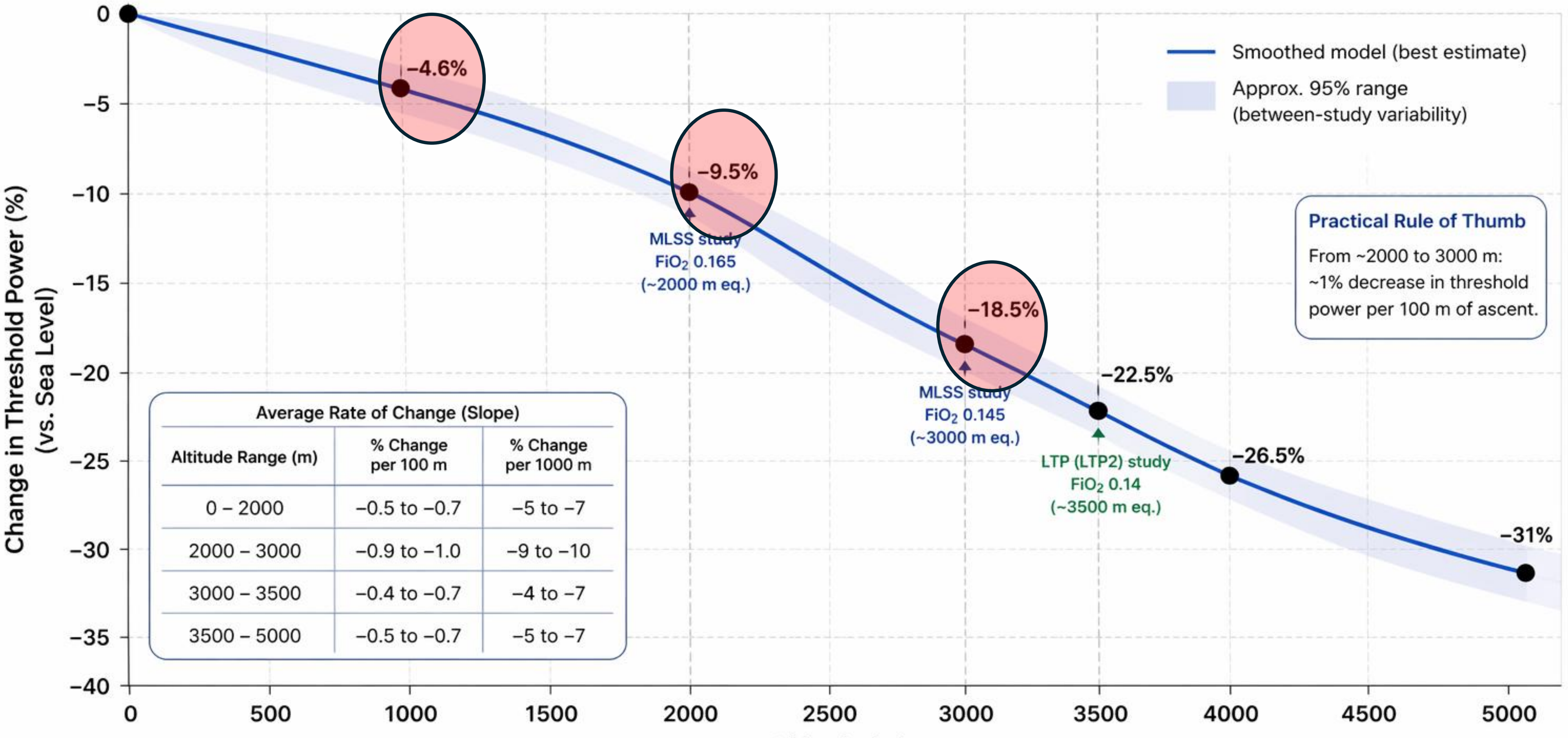
Drop in VO_2 with altitude



Wehrlin & Hallén 2006

Acute Hypoxia: Change in Threshold Power vs Altitude (Smoothed Model)

Trained Endurance Athletes (Cyclists) – Normobaric Hypoxia



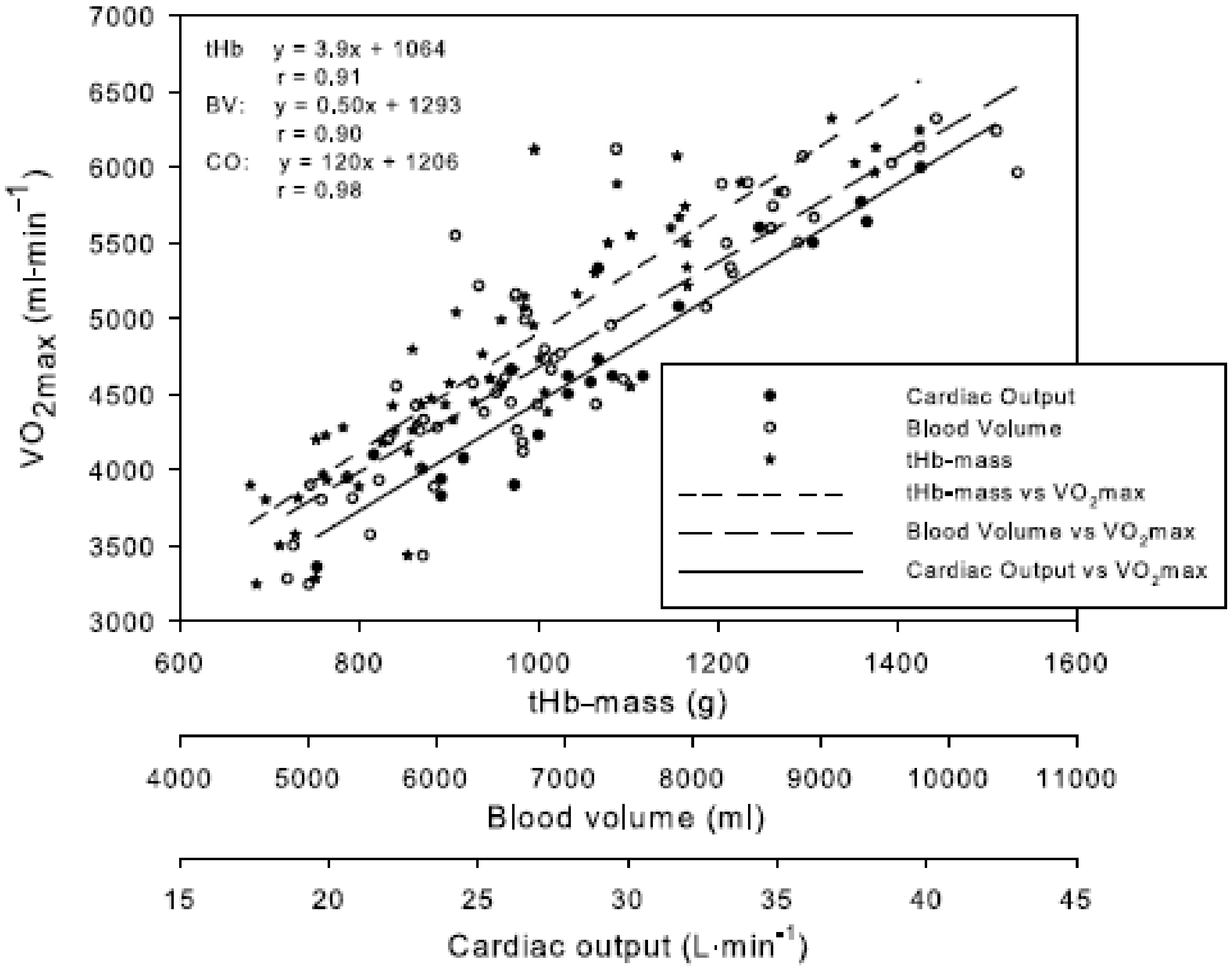
Average Rate of Change (Slope)

Altitude Range (m)	% Change per 100 m	% Change per 1000 m
0 – 2000	−0.5 to −0.7	−5 to −7
2000 – 3000	−0.9 to −1.0	−9 to −10
3000 – 3500	−0.4 to −0.7	−4 to −7
3500 – 5000	−0.5 to −0.7	−5 to −7

~18% FiO_2 ~16% FiO_2 ~14% FiO_2

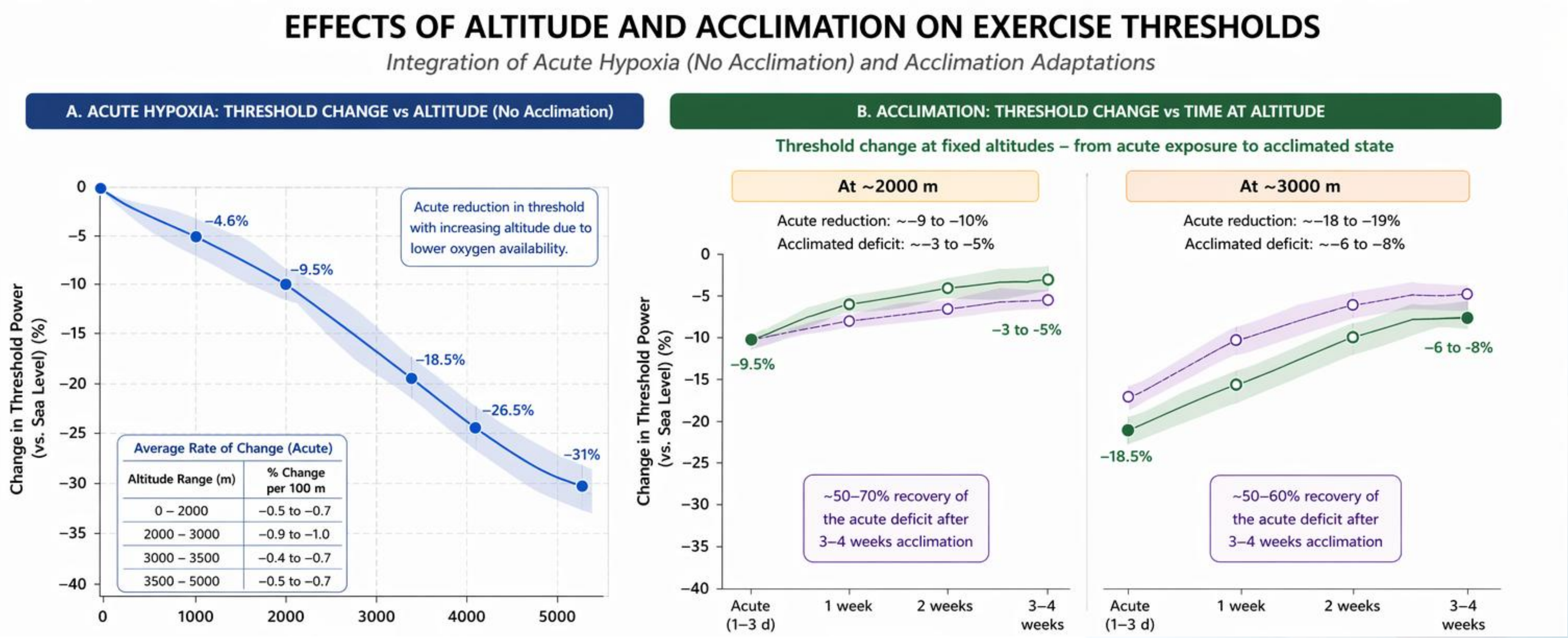
Ofner et al. 2014; Faulhaber et al. 2021: Bazanska-Janas et al. 2026

Adaptation to hypoxia



Schmidt W & Prommer N. Exerc Sports Sci Rev 38: 68-75, 2010

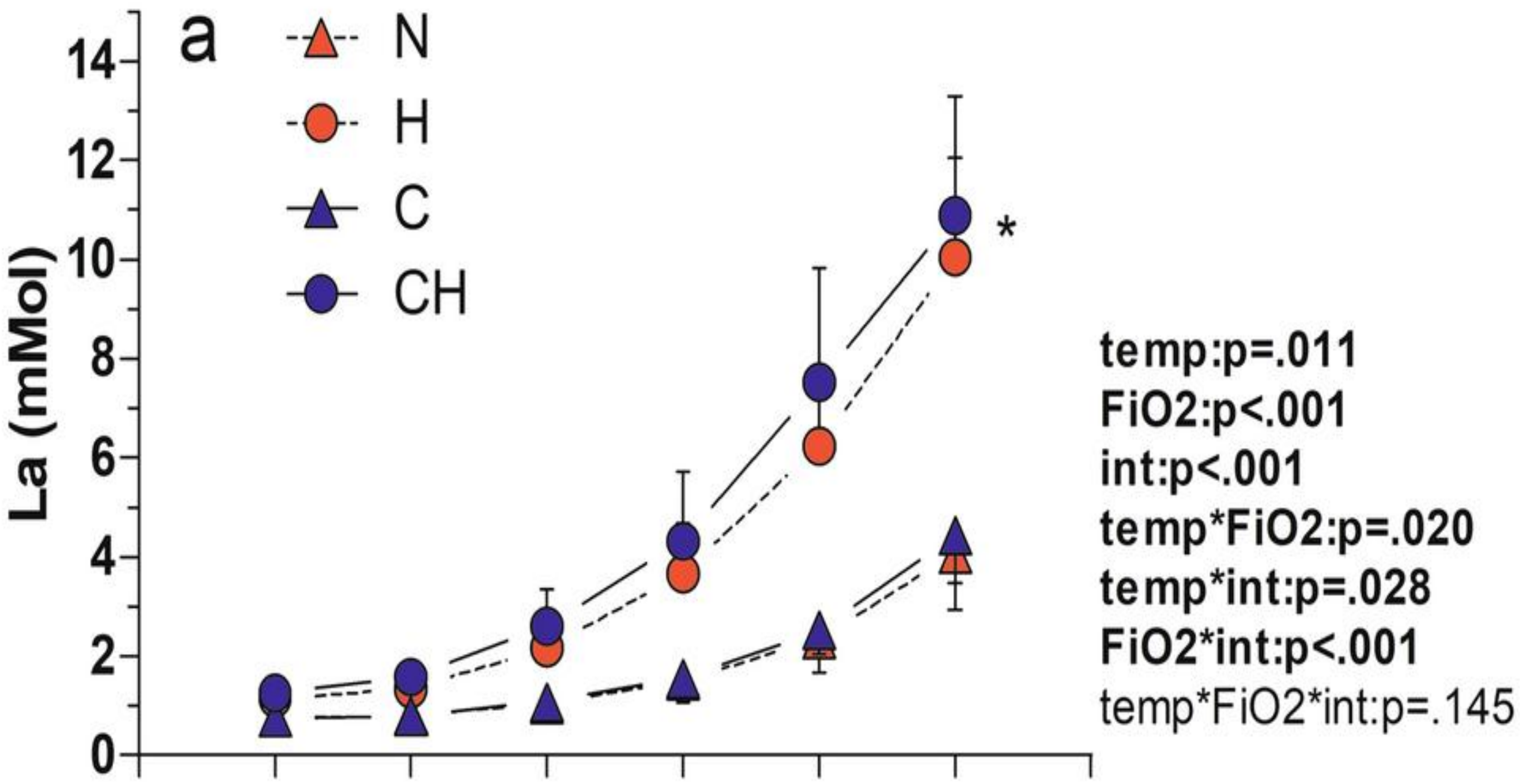
Adaptation to hypoxia



https://hula.fi/ep2/fi/materiaali/muu-materiaali/

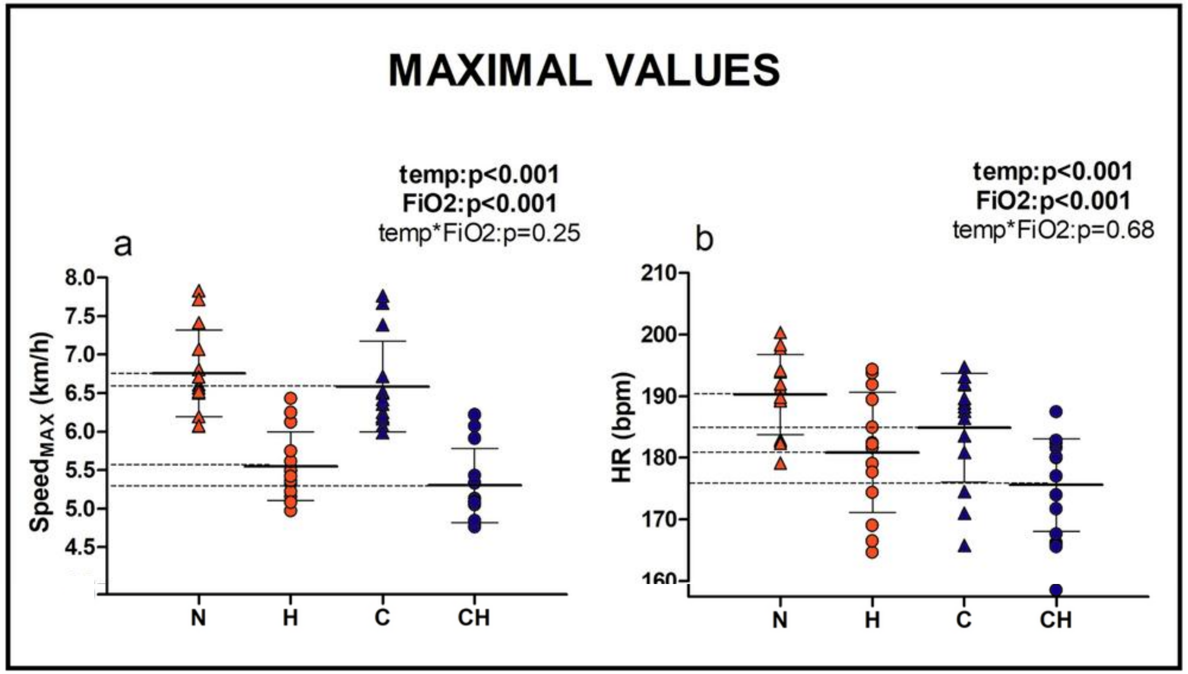
TIME		CONTROL EXERCISE IN NORMOXIA AND/OR AT ALTITUDE Control exercise. Modify as needed. Example: Step incremental 4 x 4 min REST					
Date yyyy-mm-dd	Days #	Altitude m	HR bpm	La mmol/l	SpO_2 %	SpO_2:Altitude Index	RPE 0-10
2021-08-17		*2400*	*70*	*1,5*	*94*	*3,92*	*7*
						DO NOT FILL	
PRE ALTITUDE (SEA LEVEL)							
	1					#DIV/0!	
	2					#DIV/0!	
	3					#DIV/0!	
	4					#DIV/0!	
	5					#DIV/0!	
	6					#DIV/0!	
	7					#DIV/0!	
	8					#DIV/0!	
	9					#DIV/0!	
	10					#DIV/0!	
PRE ALTITUDE AVERAGE							
ALTITUDE							

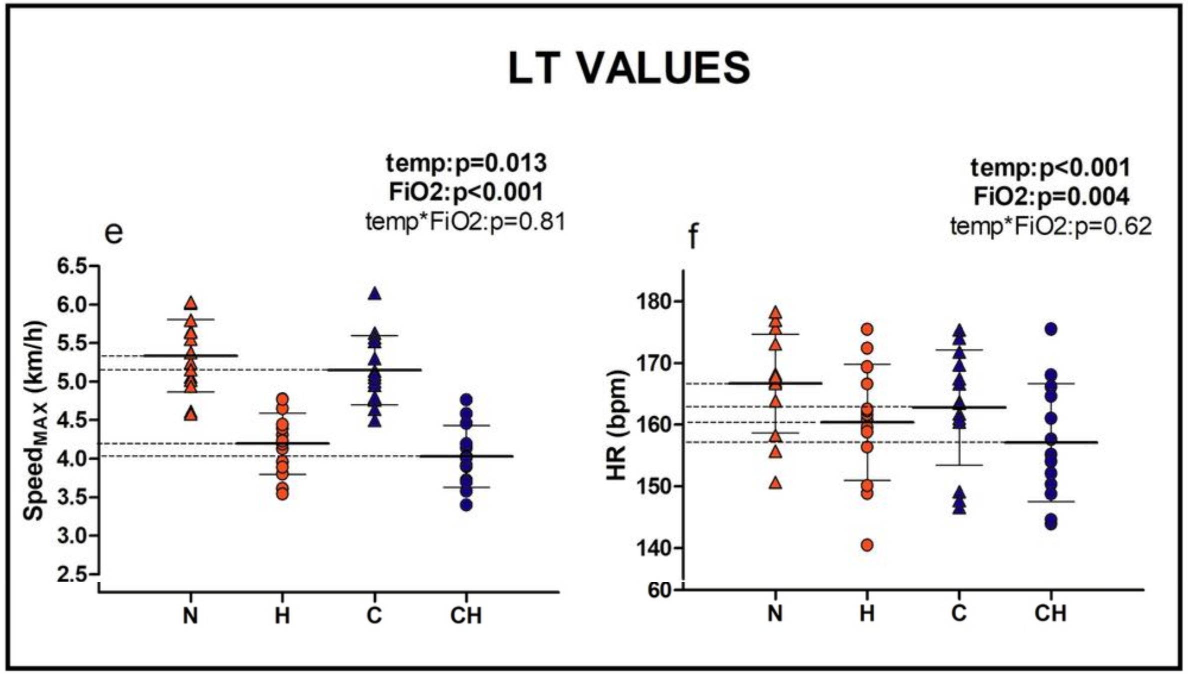
Interactions?



Callovini et al. 2024

Interactions – Cold and Hypoxia
Additive and synergic effects





N normothermic normoxia
H normothermic hypoxia
C cold normoxia
CH cold-hypoxia

Exercise duration?

While heat stress and hypoxia have minimal impact on sprint performance, cold also diminish sprint performances.

Recommendations

- There are no clear prediction model supporting changes in exercise performance thresholds across different environments.
- Establish competition environment.
- Test (possibly train) in that environment as much as possible.

Kiitos - hula.fi/ep2