Heat versus hypoxic acclimation to improve physiological responses in a hypoxic environment

Adaptation and Cross Tolerance to Environmental and Metabolic Stressors: From the Patient to the Athlete

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Introduction

- Heat acclimation ergogenic under heat stress (& temperate?)

- **Cross acclimation**: *"Adaptations made at a physiological level in response to one environmental stressor (e.g. Heat) are beneficial in another (e.g. Hypoxia.)"*

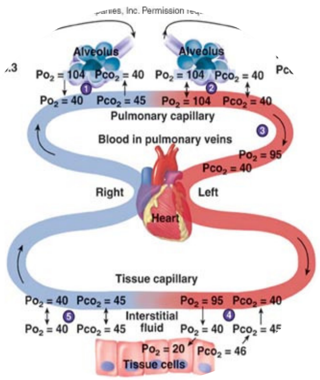
Why?	Hypoxic/Altitude Interventions	Heat Interventions
Access	Access to artificial and terrestrial altitude can be problematic.	Thermally stressful environments generally more attainable.
Time	Prolonged sojourns at altitude not possible	Heat adaptation more expedient
Variability	Variability in response to LLTH / IHT interventions	Heat adaptations appear more consistent
Tolerance	Appropriate for those initially less tolerant to repeated hypoxic exposures	Heat stress well tolerated in young, trained individuals

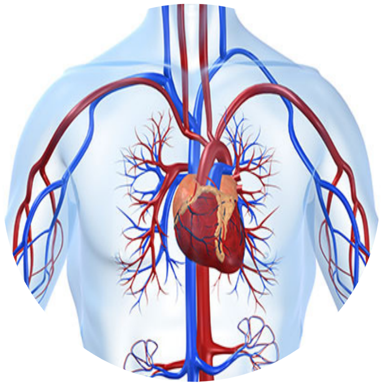
Mechanisms? Calbet et al., (2003)

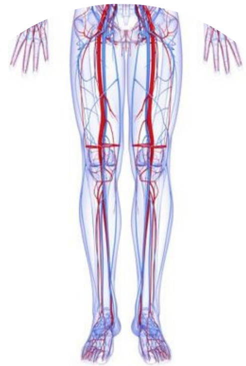
AJPRICP 284:R291-R303

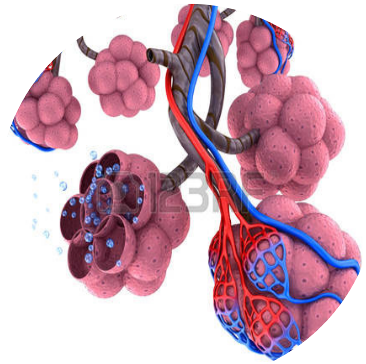
Determinants of maximal oxygen uptake in severe acute hypoxia

Limitations







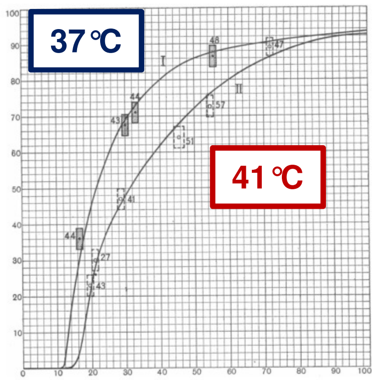


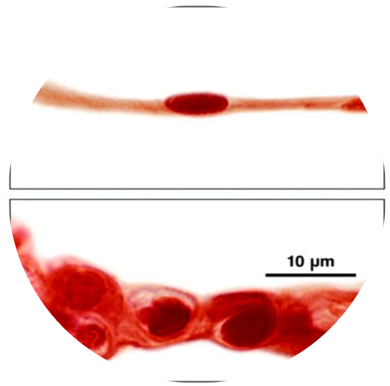
Low PiO_2

Reduced Q and peak leg blood flow

Impaired pulmonary gas exchange

Heat/Cross Acclimation Phenotype





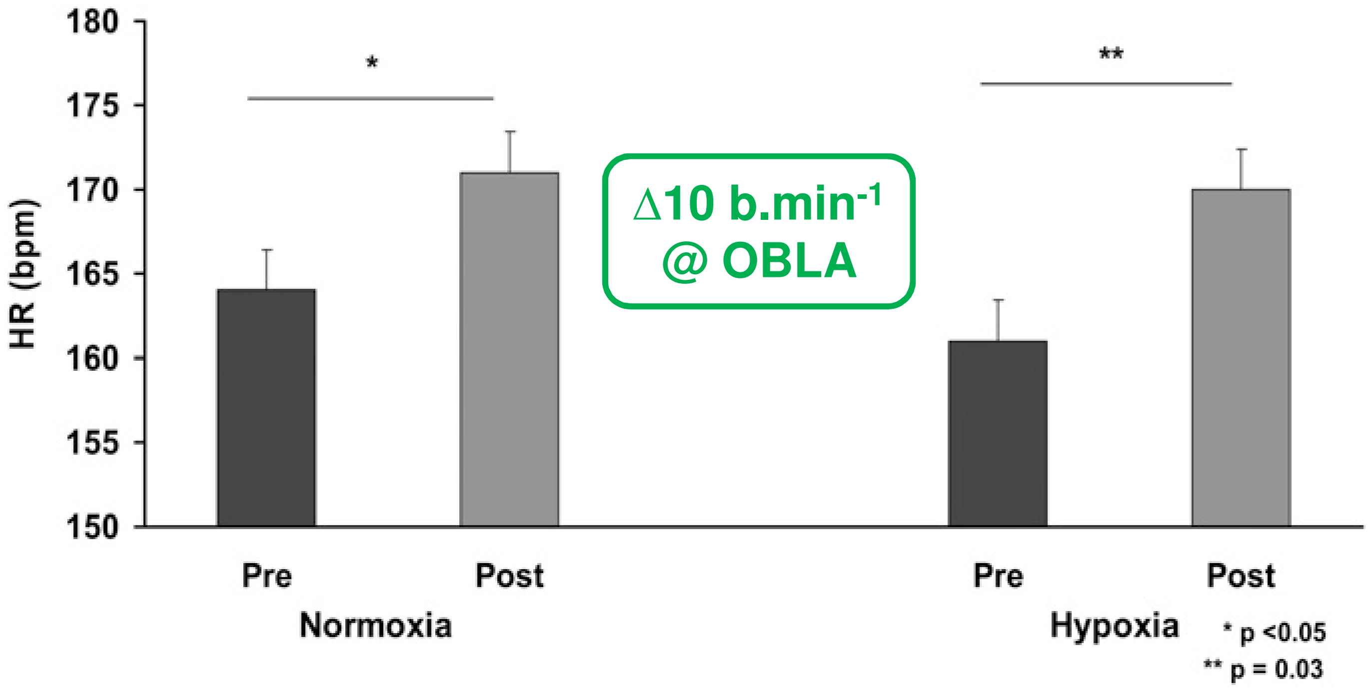
Heled et al., 2012

Aviation, Space, and Env Med 83 (7) 649-653

Heat Acclimation and Performance in Hypoxic Conditions

12 days. 120 min.day^{-1}
40℃ 40% R.H.[Fixed] Walking @ 30% $\dot{V}O_{2peak}$

OBLA test
FiO_2 = 0.15; ~2,500 m



Gibson et al., (2015)

J Appl Phys 119:889–99

Heat acclimation attenuates physiological strain and the HSP72, but not HSP90α, mRNA response to acute normobaric hypoxia.

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10 days 90 min.day^{-1} 40°C 40% R.H. [ISO] Cycling @ 65% $\dot{V}O_{2peak}$	10 min rest, cycling@ 40% $\dot{V}O_{2peak}$ @ 65% $\dot{V}O_{2peak}$ $FiO_2 = 0.12$; ~4,500m

- HA successfully induced heat acclimated phenotype in normoxia

✓ Decreased rest T_{rec} (-0.49°C)

✓ Decreased HR (-18 b.min^{-1})

✓ Plasma & Blood Volume expansion (+15%)

✓ Increased Sweat Rate (+48%)

Gibson et al., (2015)

J Appl Phys 119:889–99

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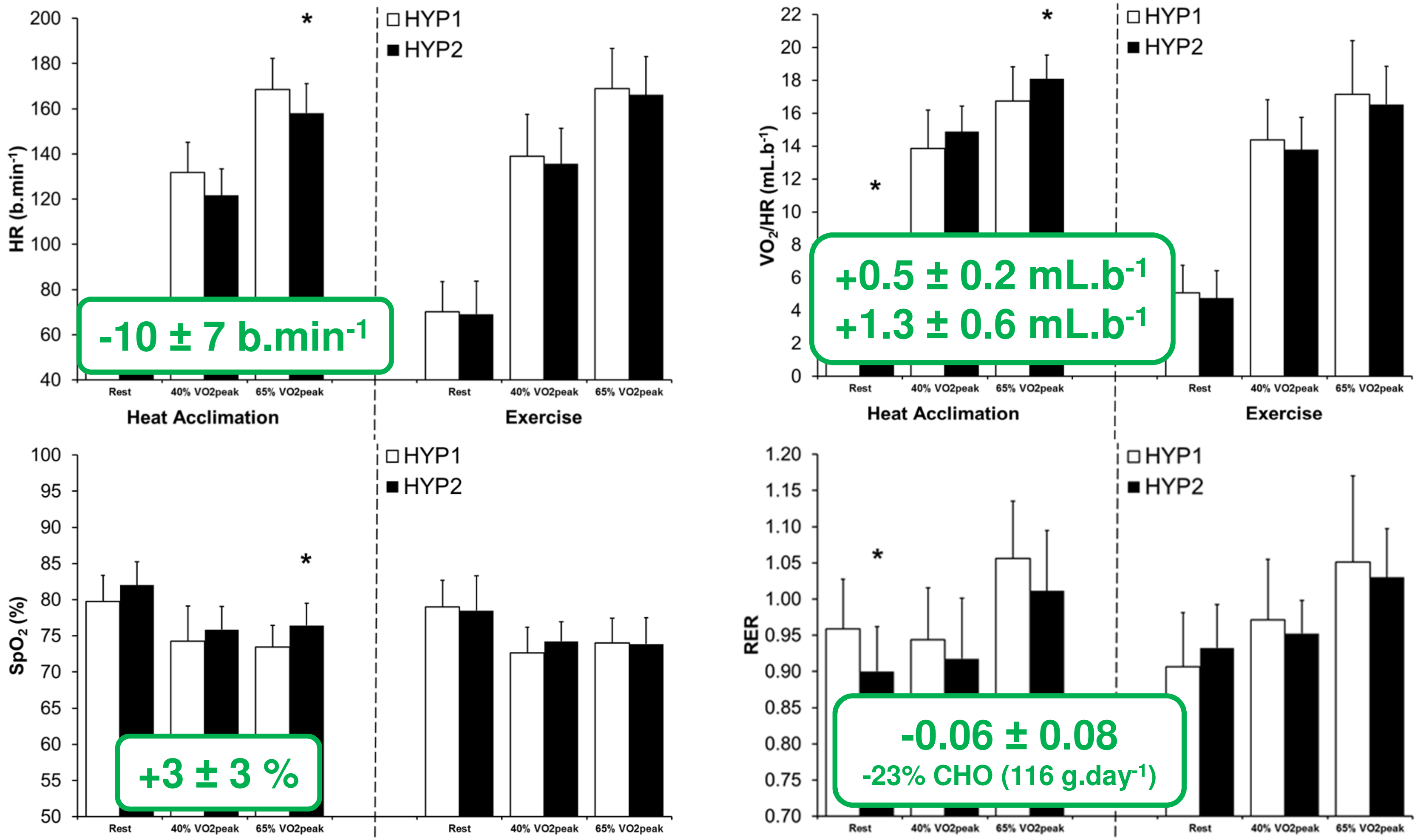
10 min rest, cycling@ 40% $\dot{V}O_{2peak}$ @ 65% $\dot{V}O_{2peak}$
FiO_2 = 0.12; ~4,500m

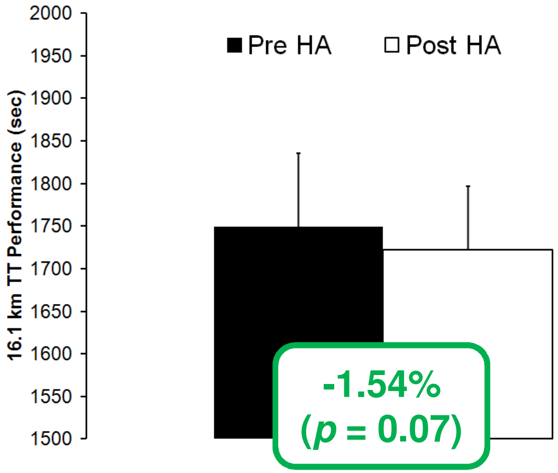


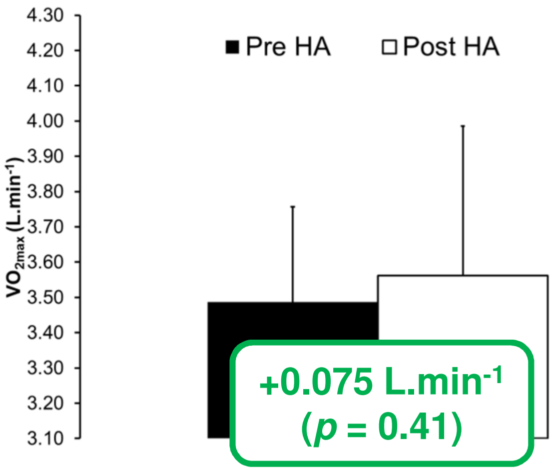
White et al., (2016)

Temperature 3:1 176-185

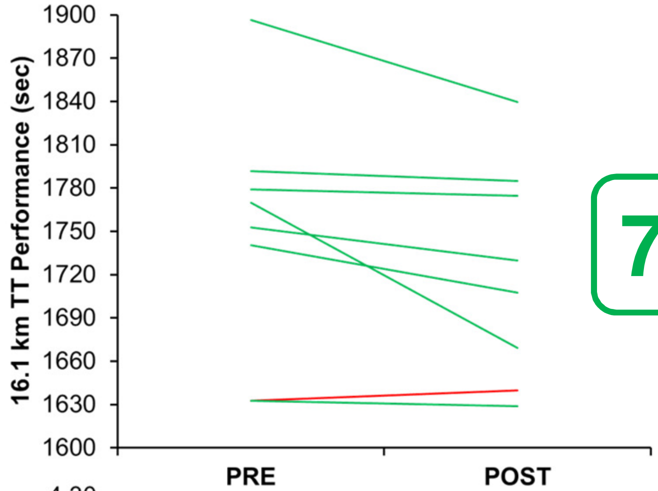
The effect of ten days of heat acclimation on exercise performance in acute hypobaric hypoxia (4350 m)

10 days 2x 50 min.day^{-1} (10 min rest)
40°C 55% R.H. (1,600m residential altitude)
[Fixed] Cycling @ 50% $\dot{V}O_{2peak}$

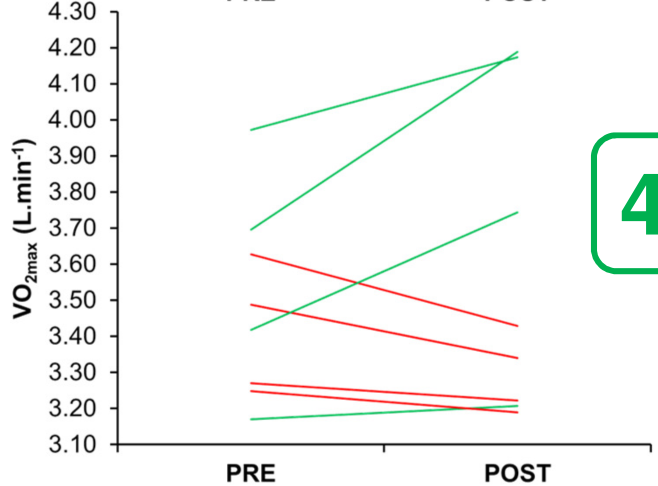




VO_{2max} test & 16.1km cycling TT
$FiO_2 \approx 0.12$; 4,350m



7/8 ↑



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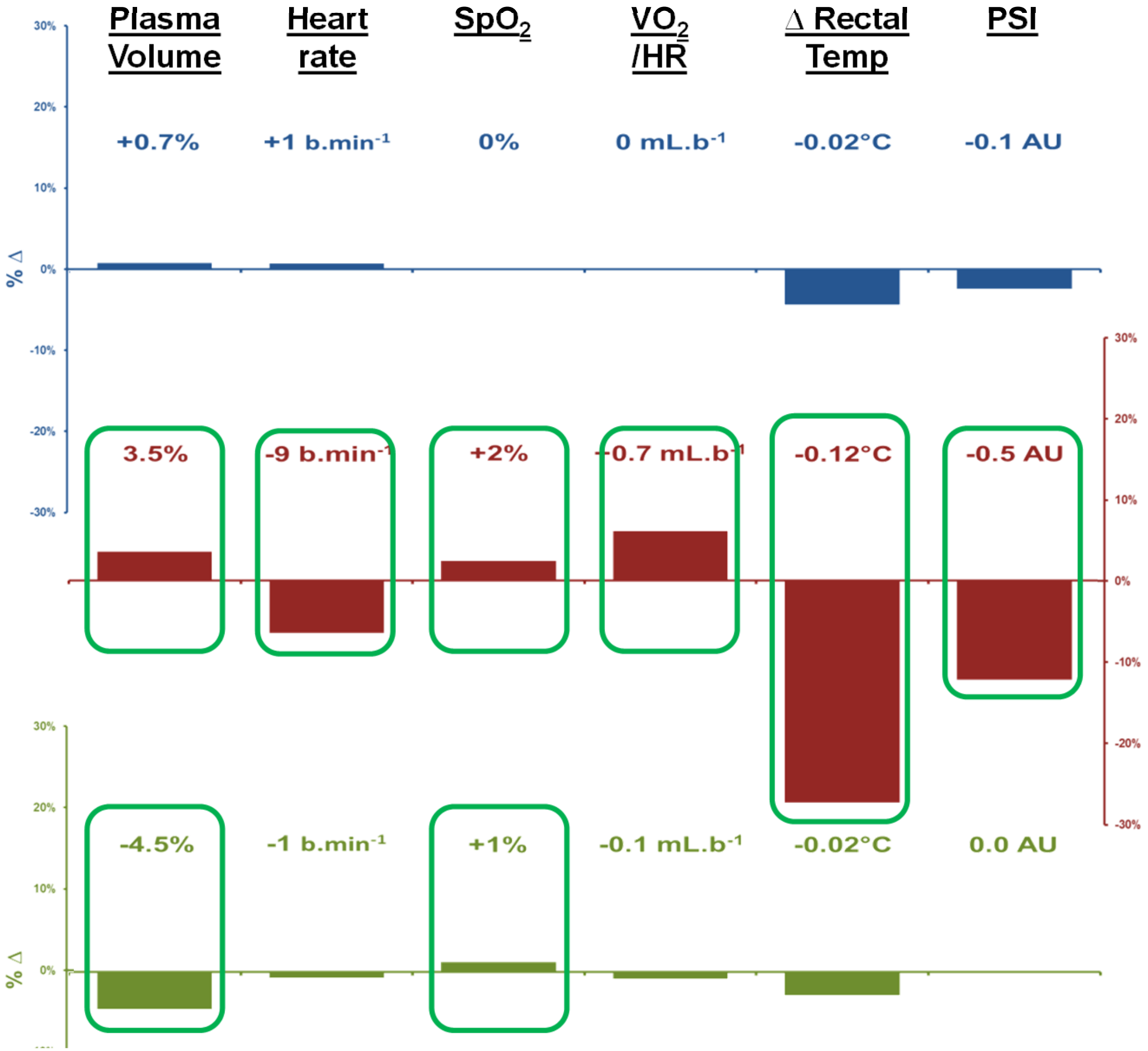
Lee et al., (2016)

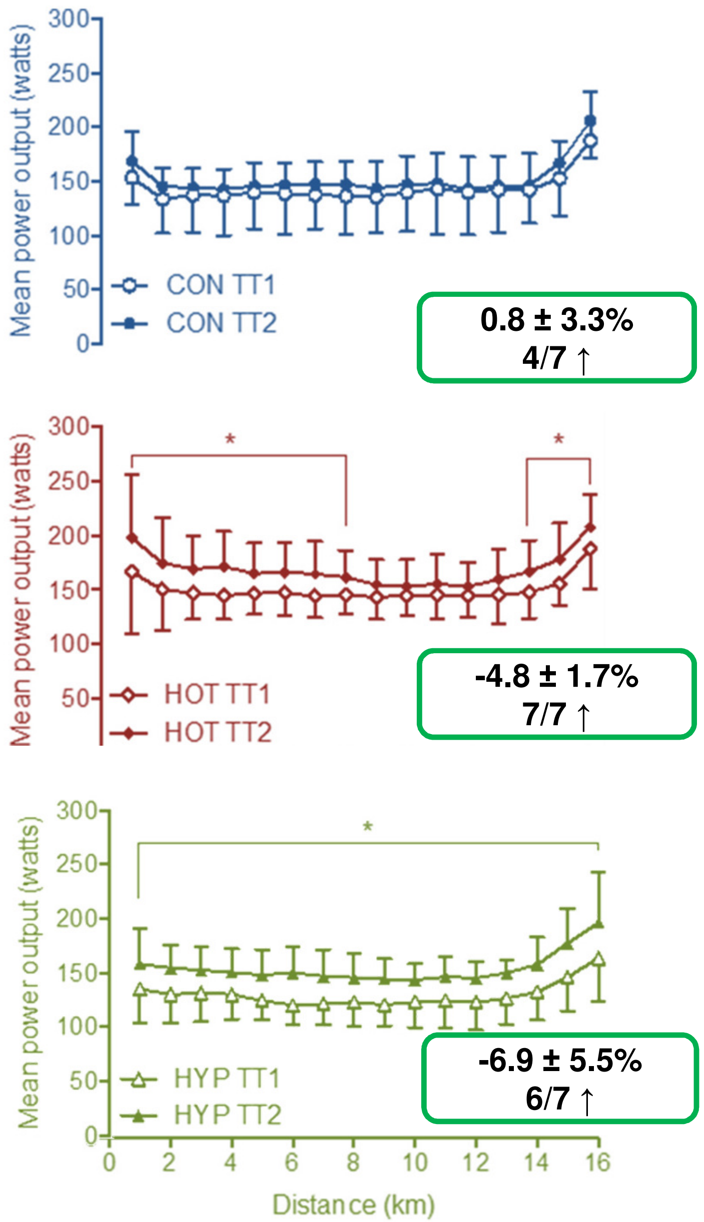
Frontiers in Exercise Physiology. 7: 78.

Cross acclimation between heat and hypoxia: Heat acclimation improves cellular tolerance and exercise performance in acute normobaric hypoxia

40 min @ 50% $\dot{V}O_{2peak}$
16.1km cycling TT
FiO_2 = 0.14; ~3,300 m

10 days 75 min.day^{-1} (incl 15 min rest)
[Fixed] Cycling @ 50% $\dot{V}O_{2peak}$ in CON, HOT, HYP





Is the duration of heat acclimation important?
Lee et al., 2014a; *Ext physiol & med* 3:15 . 1-16

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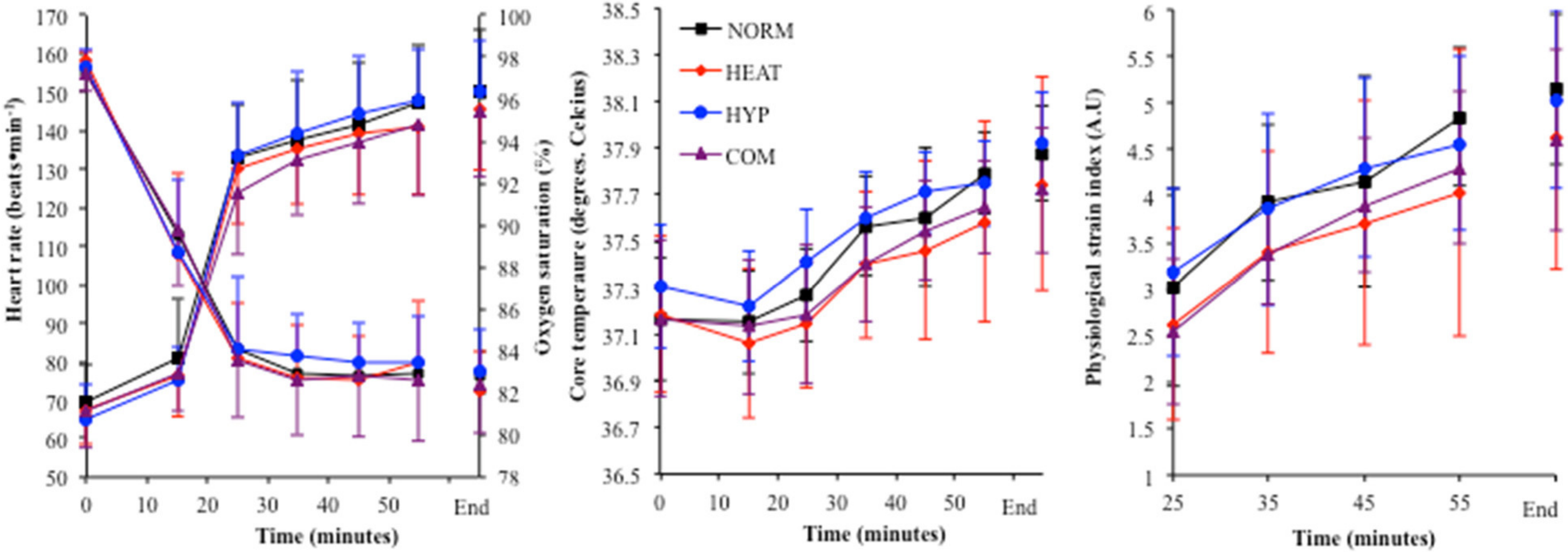
75 min (15 min preliminary rest)
[Fixed] Cycling @ 50% $\dot{V}O_{2peak}$

15 min @ rest 60 min @ 50% $\dot{V}O_{2peak}$
FiO_2 = 0.14; ~3,300 m



NORM (FiO_2 ≈ 0.21, 20°C) vs HEAT (FiO_2 ≈ 0.21, 40°C) vs HYP (FiO_2 ≈ 0.14, 20°C) vs HEAT + HYP (FiO_2 ≈ 0.14, 40°C)

HR	No difference	**Core Temperature**	No difference
SpO_2	No difference	**Physiological Strain Index**	No difference

Is the duration of heat acclimation important?
Lee et al., 2014b; *BioMed Res Int'l* 72: 849809. 1-16

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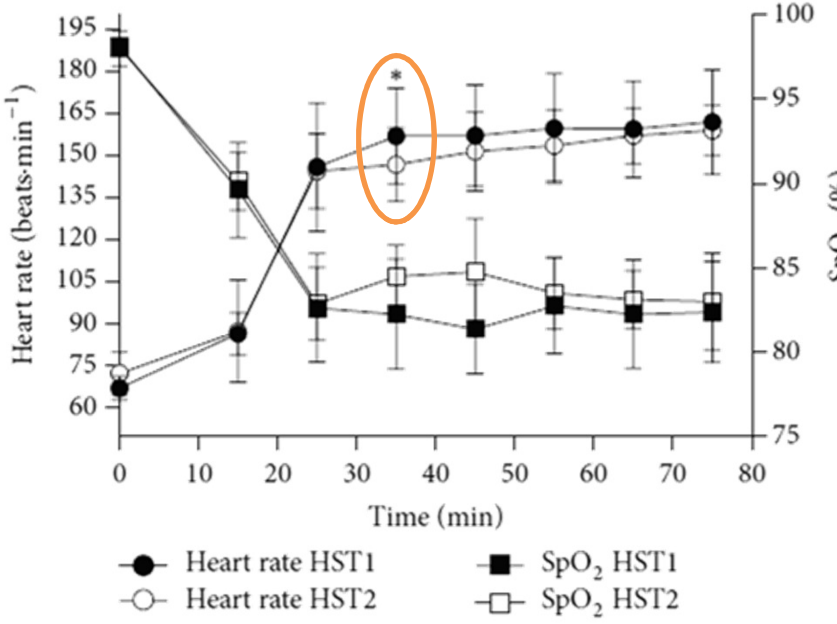
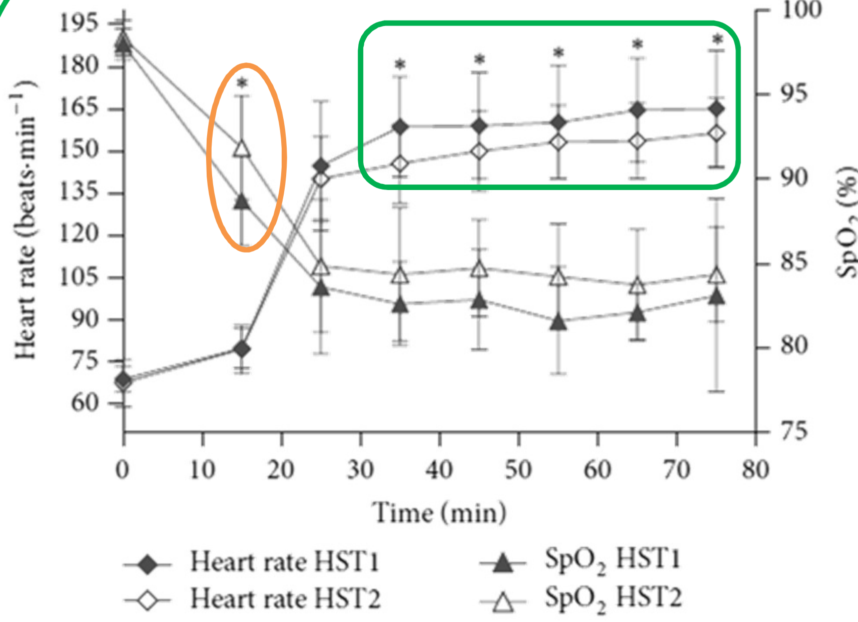
3 days 75 min.day^{-1} (15 min preliminary rest)
40°C 20% R.H. [Fixed] Cycling @ 50% $\dot{V}O_{2peak}$

15 min @ rest 60 min @ 50% $\dot{V}O_{2peak}$
FiO_2 = 0.14; ~3,300 m



(a)



(b)

CON

HR	No difference
SpO_2	No difference

HA

HR	-9 b.min^{-1}
SpO_2	No difference

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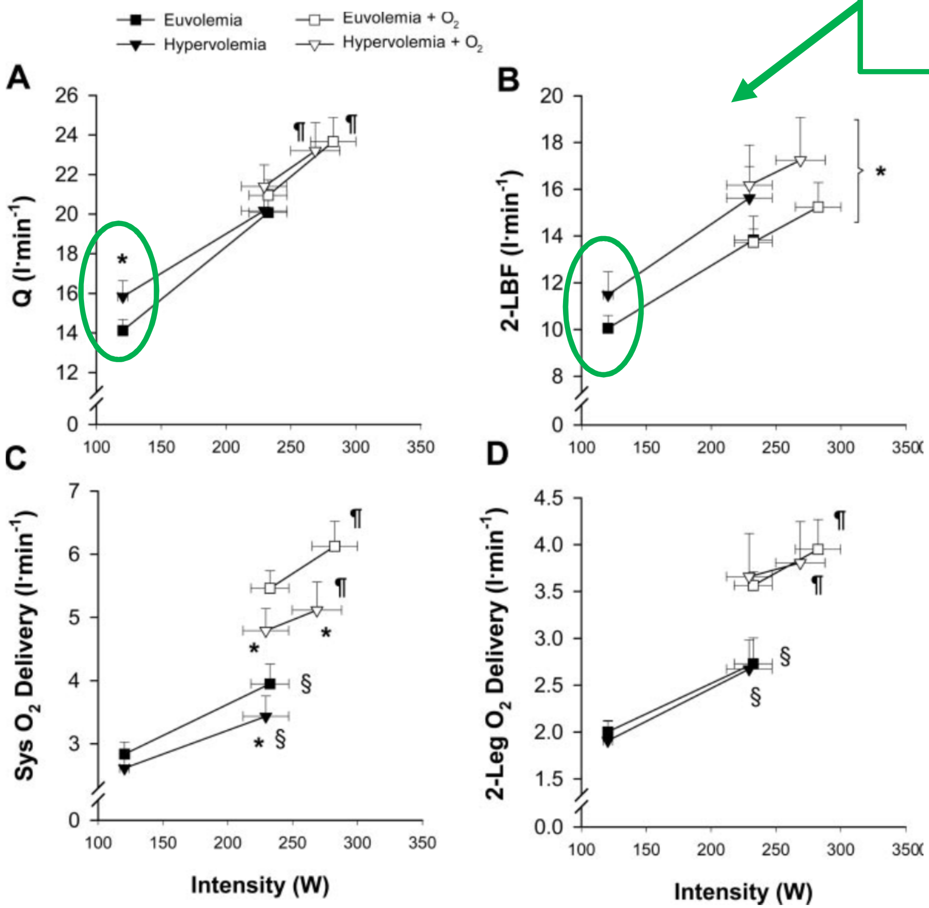
Mechanisms?

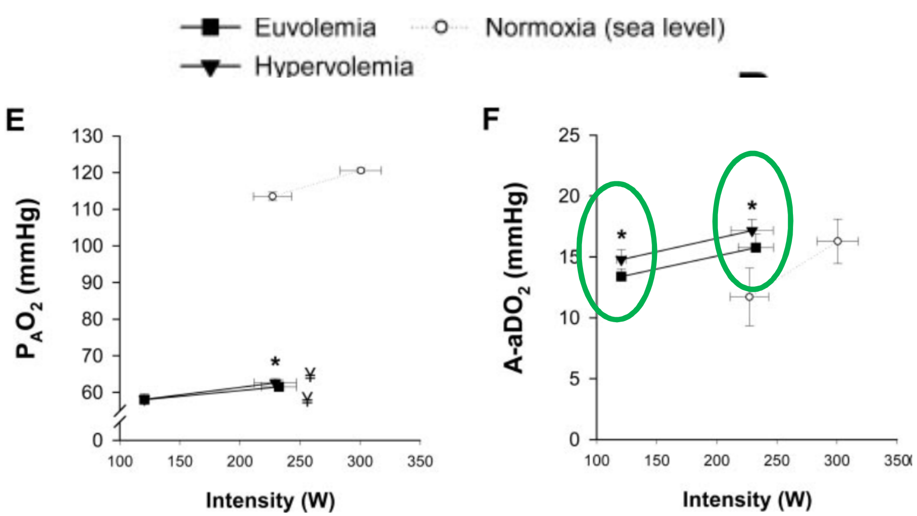
Calbet et al., (2004) *AJPHCP 287:R1214-R1224*

Plasma Volume expansion does not increase maximal cardiac output or VO_{2max} in lowlanders acclimatized to altitude

Submaximal (but not maximal) **limb blood flow and cardiac output increase**

Submaximal **and** maximal alveolar-arterial PO_2 gradient increase





Mechanisms?

Singhi et al., (2005) *Annals of Tropical Paediatrics 25, 243-252*

Body water and plasma volume in severe pneumonia: implications for fluid therapy

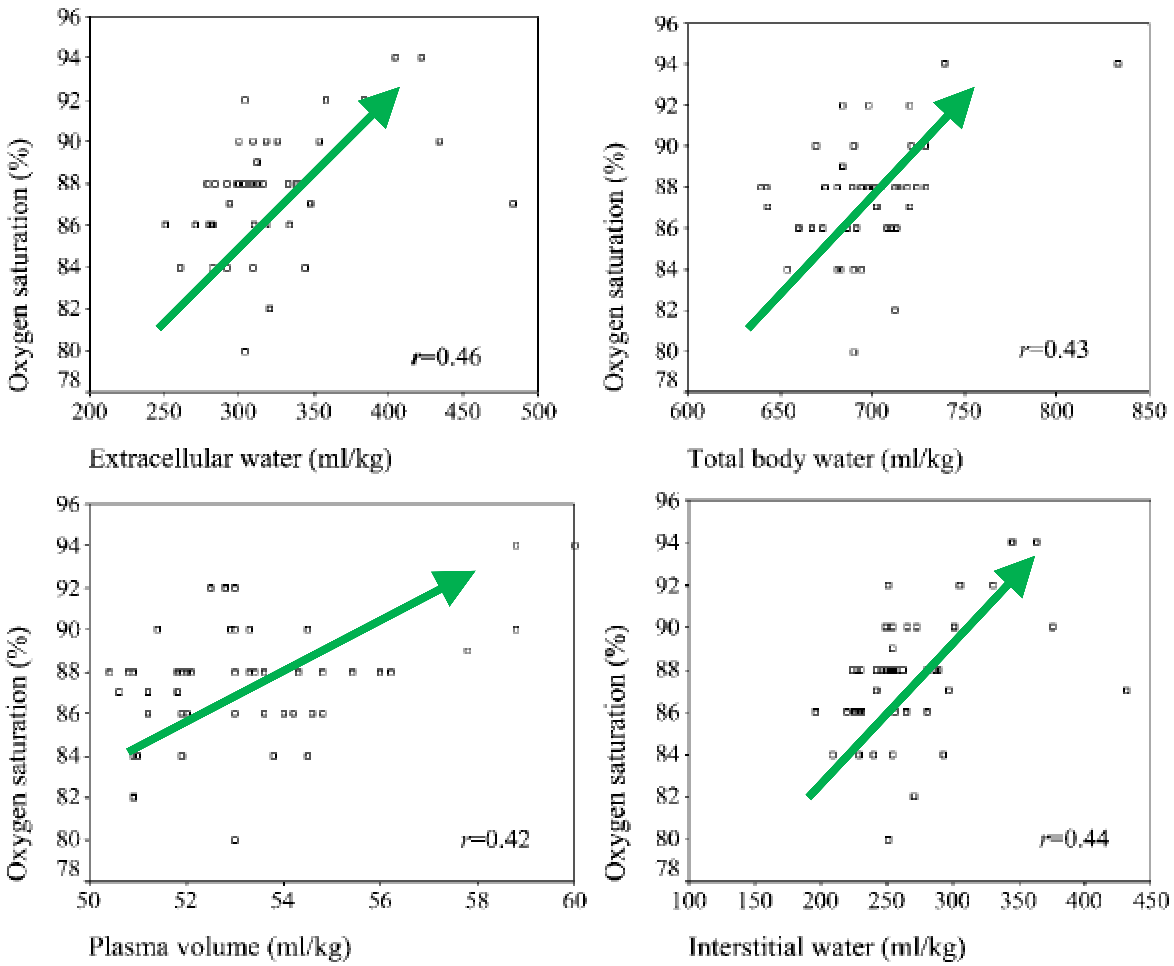


FIG. 1. Correlation between oxygen saturation (SpO_2) and various body water compartments.

"ECW and PV were moderately increased in pneumonia …….. increase correlated with better oxygenation."

Conclusions

- Improved physiological responses to (normobaric) hypoxia
- Improved endurance performance in (normobaric) hypoxia
  - tbc in hypobaric hypoxia
- Magnitude of benefits may be reduced/limited in those acclimatized to altitude.
- Mechanistic work required to support applied understanding

Future directions

- Identify mechanisms more clearly
  - ? Plasma Volume
  - ? Temperature
- Determine benefits across spectrum of simulated and terrestrial ascents
  - ✓ >3,000 - 4,000m
  - ? 1,500 – 2,500m?
- Identify exercise intensity domains whereby cross acclimation may effectively occur
  - ✓ Moderate intensity
  - ? Low & High intensity

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