Innovations in hypoxic training

Raphael Faiss, PhD
Senior Scientist
Endurance Physiology Group (Cycling), Section for Elite Sport

raphael.faiss@baspo.admin.ch
@wattsnow
Panorama of contemporary altitude training strategies

Altitude/Hypoxic Training

LHTH

Natural/Terrestrial

Nitrogen dilution

Supplemental Oxygen

LHTL

Oxygen filtration

LHTLH

IHE

IHIT

IHIT

LLTH

IHT

Updated panorama of contemporary altitude training strategies

Altitude/Hypoxic Training

LHTH (HH)

Natural/Terrestrial (HH)

LHTL (HH / NH)

Nitrogen dilution (NH)

LHTLH (HH / NH)

Supplemental Oxygen (HH)

LLTH (HH / NH)

Oxygen filtration (NH)

IHE

CHT

IHT

IHIT

RSH

Hypobaric vs. Normobaric Hypoxia

HH vs. NH

Ventilatory responses

V\textsubscript{T} & V\textsubscript{E} lower in HH
- Savourey et al. (2003) 40 min @ 4500 m
- Loeppky et al. (1997) 10 h @ 4770 m
- Tucker et al. (1983) 120 min @ 4750 m

Conkin & Wessel (2008) Critique of the EAA model

Performance?

Bonetti & Hopkins (2003) Meta-analysis

Exhaled Nitric oxide

NO decrease at altitude and lower in HH
- Donnelly et al. (2011) 12 h @ 5050 m
- Hemmingsson & Linarsson (2009) 10 min @ 5000 m
- Brown et al. (2006) 180 min @ 4200 m
- Duplain et al. (2000) 48 h @ 4559 m

Oxidative stress (OX)

Hypoxia -> increased OX
- Pialoux et al. (2009) 12 h @ 3000 m

Increased OX associated with decreased NO
- Pialoux et al. (2009) 4x6 h @ 3000 m
HH vs. NH study: 2 x 24 h hypoxic exposure

Hypobaric Hypoxia at 3000m & randomized

Normobaric Hypoxia

PRE

H+1

H+8

H+16

H+24

5 min at rest -> 6min cycling at 50% of normoxic PPO -> 10min at rest

Normoxia

Hypoxia

HH vs. NH
Performance alteration

HH (Jungfraujoch, 3540 m) vs. NH and NN (hypoxic chamber) during 26 h

Saugy et al. (in prep) Neuromuscular and cerebral responses to acute exposure to 3500 m hypobaric vs. normobaric hypoxia
HH vs. NH : published articles


Hypobaric vs Normobaric Hypoxia

**HH vs. NH**

- Saugy et al., in prep

**Ventilatory responses**

- Ventilatory responses: $V_t$ & $V_E$ lower in HH
  - Savourey et al. (2003) 40 min @ 4500 m
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**Performance ?**


**Exhaled Nitric oxide**

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**Oxidative stress (OX)**

- Oxidative stress (OX)
  - Faiss et al. 2013
  - Pialoux et al. (2009) 12h @ 3000 m

- Hypoxia -> increased OX
- Increased OX associated with decreased NO
  - Pialoux et al. (2009) 4x6 h @ 3000 m
Altitude training: vectors for performance improvement

Augmented hemoglobin mass?  

Modifications at the muscular level?

Muscle biopsies mRNA expression levels: significant modifications at muscular level after repeated sprint training in hypoxia (RSH)

- **Oxygen signaling**
  - Hif-1α
  - VEGF
  - MB
  - PGC1α

- **Oxygen carrier**
  - MB
  - VEGF

- **Mitochondrial biogenesis**
  - TFAM
  - CA3

- **pH regulation**
  - MCT-1
  - MCT-4
  - LDH

Specific molecular adaptations: shift towards increased glycolytic activity
Hoppeler & Vogt. 2001; Dufour et al. 2006; He et al. 2011

Innovation: Repeated sprint training in hypoxia (RSH)

- 50 male cyclists
- Normobaric hypoxic chamber

Hypoxic group (n=20, 3000 m, \(F_iO_2 = 14.7\%\)) \(\text{RSH}\)
Normoxic group (n=20, 485 m, \(F_iO_2 = 20.9\%\)) \(\text{RSN}\)
Control group (n=10, no training)

- 4 weeks of cycling training
- 120 sprints in 8 sessions

PRE- & POST-training tests:
Repeated sprint ability (RSA) test
(10 s all out sprint-20 s recovery) until exhaustion

Results:
mean 10 s power of all sprints (W)

• + 7% Power output
• Not more sprints

Results:
mean 10 s power of all sprints (W)

** p<0.01, * p<0.05 for difference with PRE
## p<0.01 for difference with last sprint in PRE sprint #9

+ 6% Power output
38% more sprints

70% of best

Muscle oxygenation
Muscle oxygenation during the successive sprints
-> variations in total hemoglobin $\Delta$Hb
2 weeks of double poling training (6 sessions) = 120 sprints

2 groups:
Repeated sprint training in normoxia (RSN, n=8)
Repeated sprint training in hypoxia (RSH, n=9)

Altitude simulated (double blinded): 350 m or 3000 m
Normobaric hypoxia (Altitrainer 200°)
RSH in elite cross-country skiers
Results: mean power of all sprints (W)

- + 21% Power output
- Not more sprints
Results: mean power of all sprints (W)

- + 25% Power output
- + 57% more sprints

Results:
mean power of all sprints (W)
Muscle oxygenation during the successive sprints -> variations in total hemoglobin ΔtHb

* * **##

**##

*p<0.05, **p<0.01 for difference with Pre-
## p<0.01 for difference with RSN
Conclusions after 2 RSH studies

- **Repeated sprint training in hypoxia (RSH) in cyclists**
- **Enhanced muscle perfusion**
  - **Muscle oxygenation**

**Adaptations at molecular level**

**Enhanced muscle perfusion**

**RSH with XC Skiers**

**Hypoxia**
- $\rightarrow$ compensatory vasodilation
- $\rightarrow$ intensity dependent (Casey et al. 2012)

**Fast twitch fibers**
- $\rightarrow$ recruited during sprints
- $\rightarrow$ improved $O_2$ extraction (Cleland 2012 & McDonough et al. 2005)

**Waste metabolites removal** (Endo et al. 2005)

**Less fibre fatigue** (Wilson et al. 1977)

**RSA performance improvement**
RSH vs. IHT

- Review of hypoxic training studies
  - Additional benefits in 4 / 21 IHT studies
  - 5 / 5 RSH studies

- RSH differ from IHT
- RSH more potent than RSN!
- RSH efficiency: fiber-type dependent

- Proposed mechanisms for further investigations
  - [PCr] resynthesis
    Hypoxic stimulus + training => modulation of [PCr] (Holliss et al. 2013)
  - Exercise: rest ratio and direct application in team sports

Advancing hypoxic training in team sports: from intermittent hypoxic training to repeated sprint training in hypoxia


ABSTRACT
Over the past two decades, intermittent hypoxic training (IHT), that is, a method where athletes live at or near sea level but train under hypoxic conditions, has gained unprecedented popularity. By adding the stress of ‘anaerobic’ or ‘anaerobic’ interval training, it is believed that IHT would potentiate greater performance improvements compared to similar training at sea level. For long, erythrocYTE was believed to be the primary factor benefitting sea-level performance improvement and sufficient (several weeks) hypoxic stimulus extended stay in altitude. By adding the stress of hypoxia during ‘anaerobic’ or ‘anaerobic’ interval training (IHT), it is believed that IHT would potentiate greater performance improvements compared to similar training at sea level.
RSH and innovation in altitude training: published articles


Immediate perspectives: RSH in team sports

Football
Franck Brocherie

Rugby
Adam Beard

Basketball
Orlando Magic (NBA)
Thank you for your attention!

Raphael Faiss, PhD
raphael.faiss@baspo.admin.ch
@wattsnow