



Unil

UNIL | Université de Lausanne

Institut des sciences du sport
de l'Université de Lausanne

Prof. Grégoire Millet

Combining hypoxic methods to maximize physical performance

From endurance athletes... to team sport players... and patients

Altitude/Hypoxic Training

LHTH

1960-



Altitude/Hypoxic Training

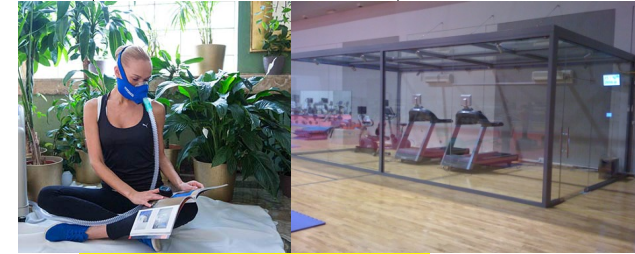
LHTH

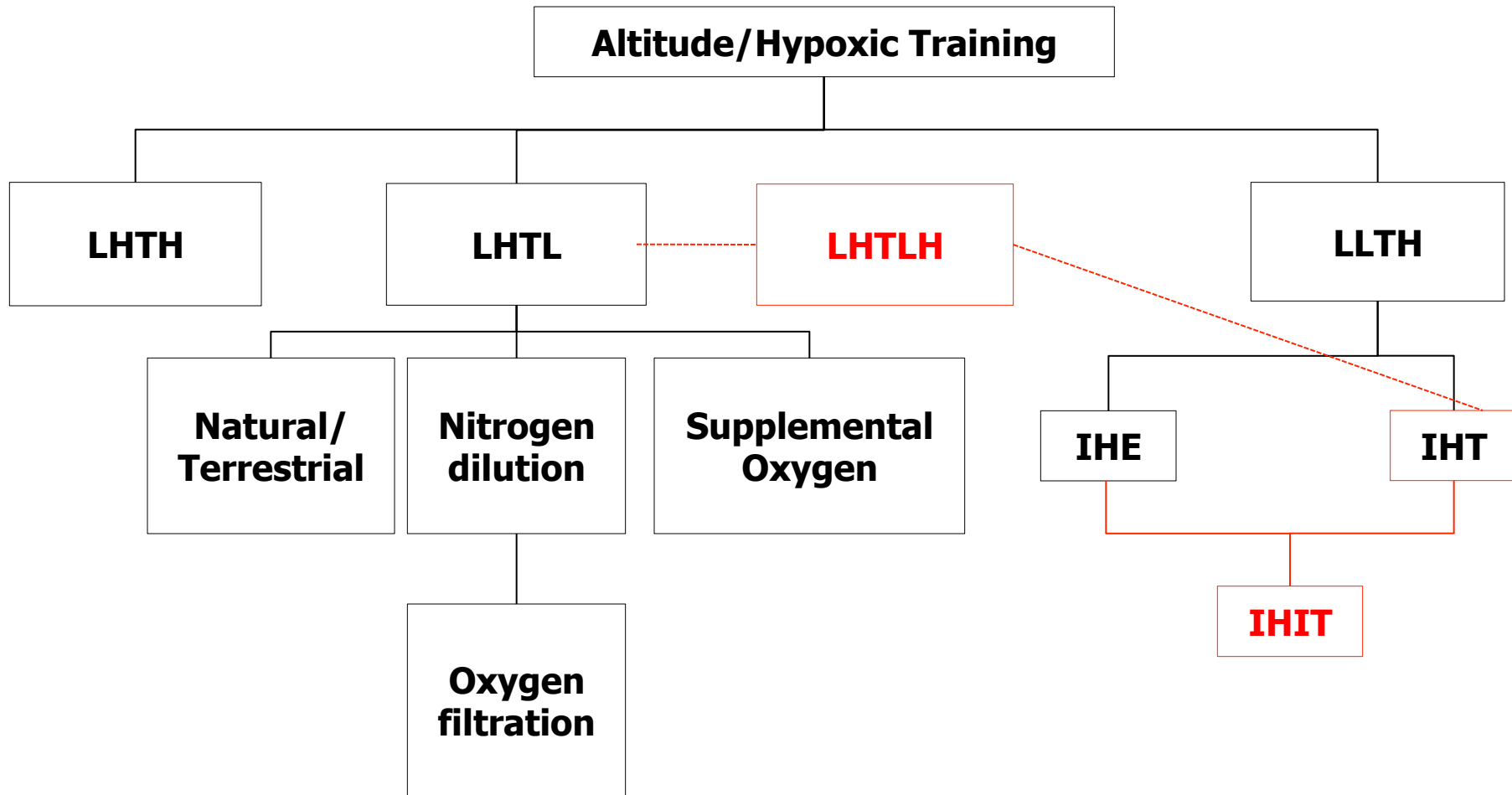
1960-



LLTH

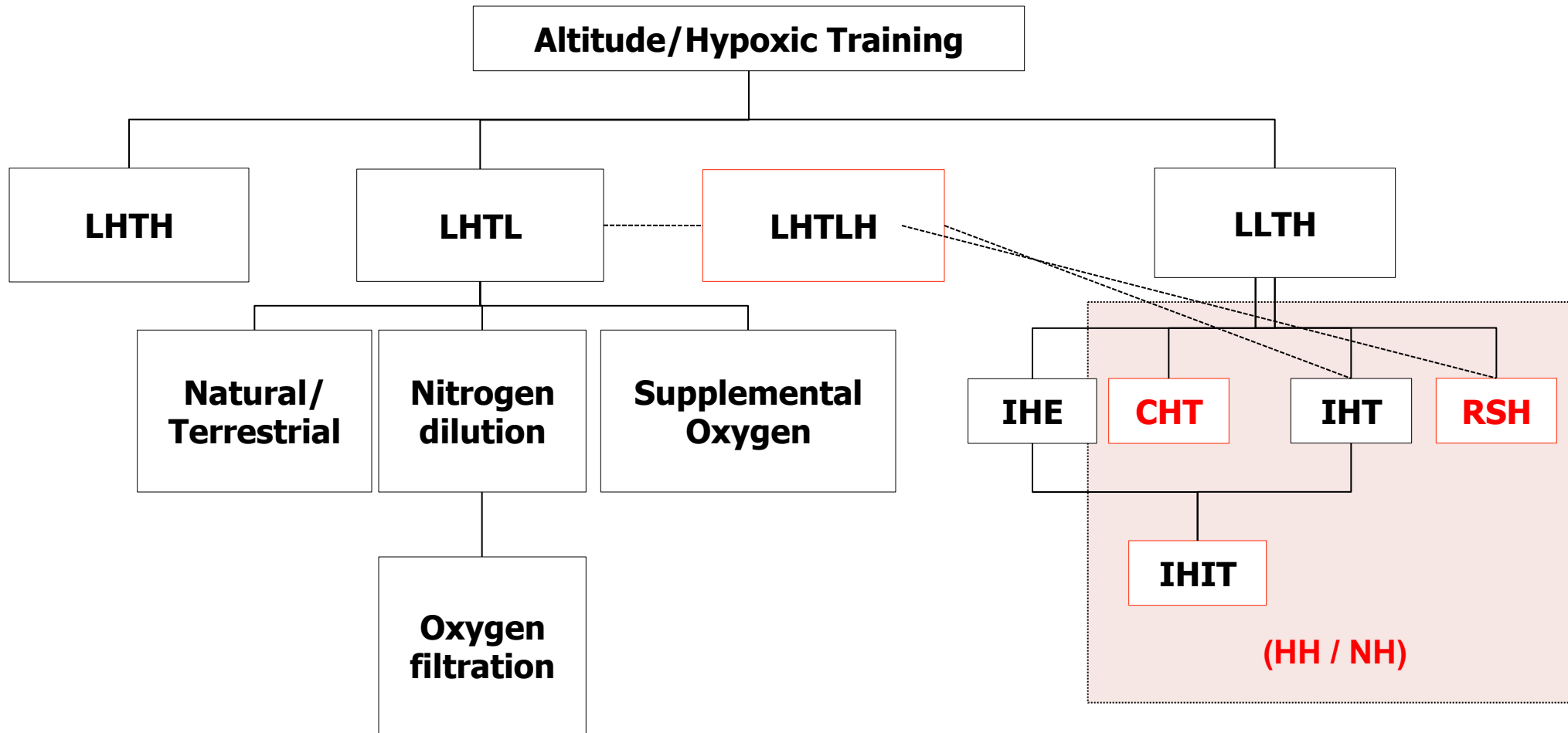
**URSS ? 1950
2000 -**





Millet et al (2010) Combining hypoxic methods for peak performance. Sports Med

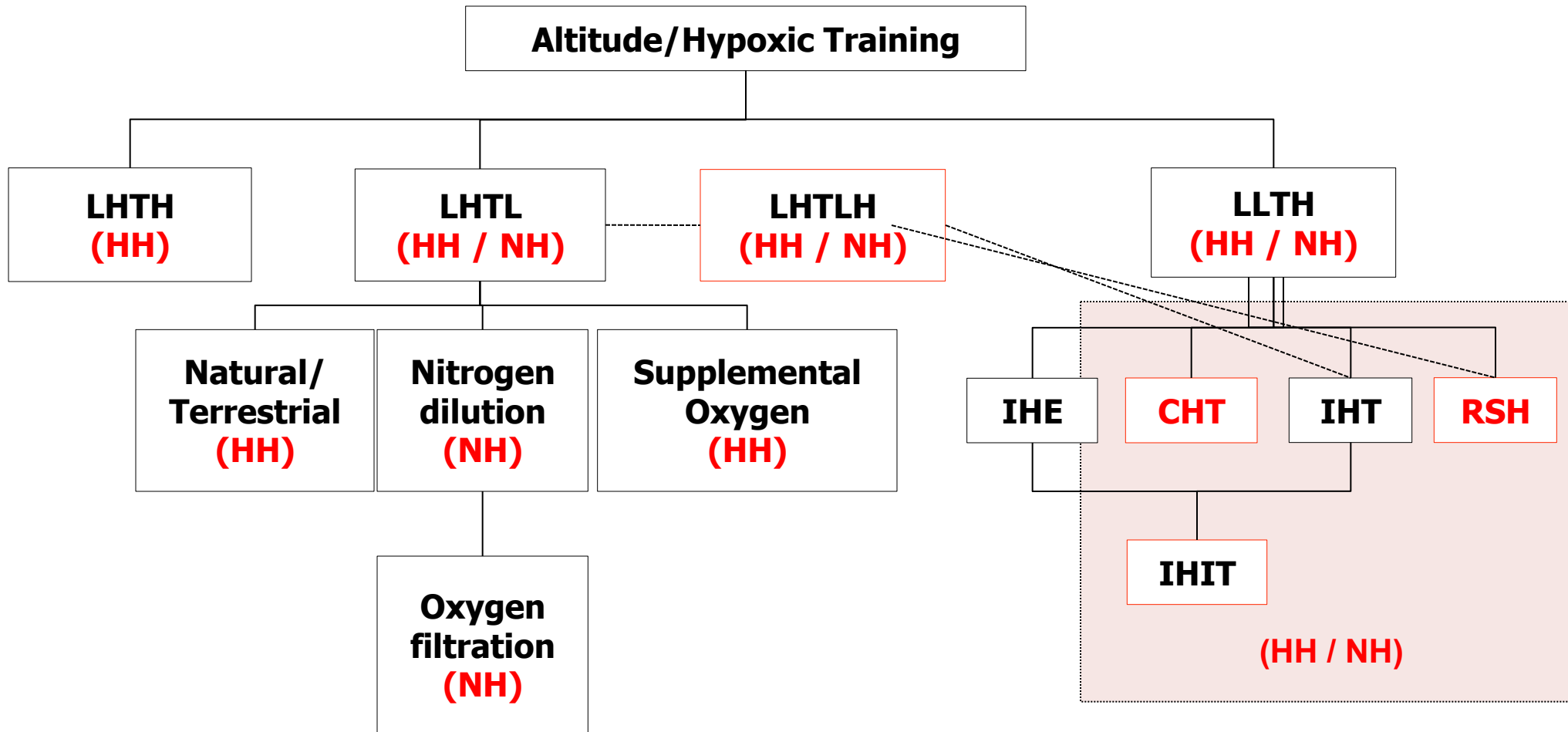
Wilber (2007) Application of altitude/hypoxic training by elite athletes. Med Sci Sports Exerc



Millet et al (2013) Hypoxic training and team sports: a challenge to traditional methods? Br J Sports Med

Millet et al (2010) Combining hypoxic methods for peak performance. Sports Med

Wilber (2007) Application of altitude/hypoxic training by elite athletes. Med Sci Sports Exerc



Millet et al (2013) Hypoxic training and team sports: a challenge to traditional methods? Br J Sports Med

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Why ?

Underlying mechanisms

How ?

Erythropoiesis vs. non-hematological factors

LHTH vs. LHTL vs. IHE/IHT (IHIT and LHTLH)

Altitude x duration / intensity

HH (terrestrial) vs NH (simulated)

for Who ?

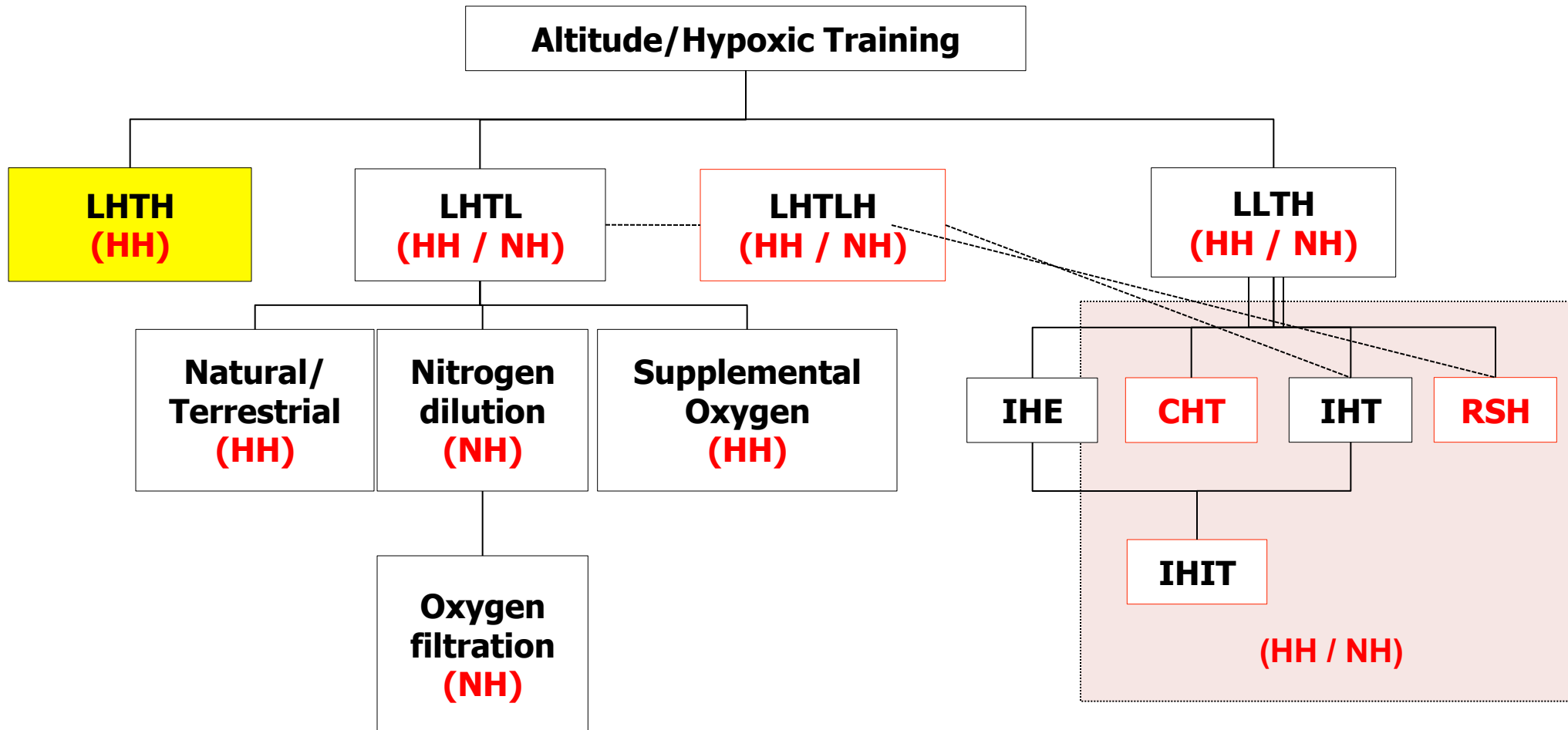
Endurance vs. “lactic” vs. intermittent sports

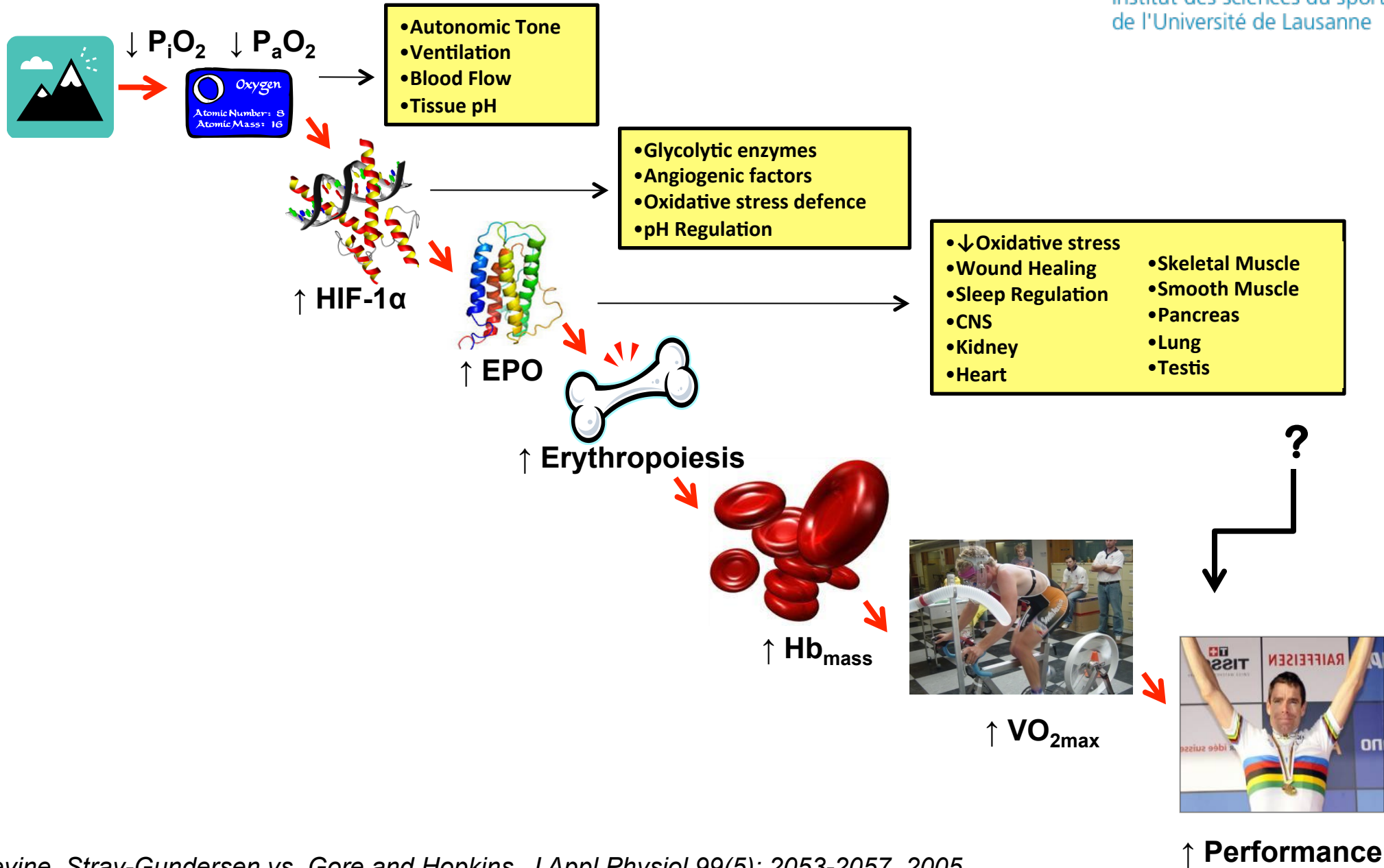
When ?

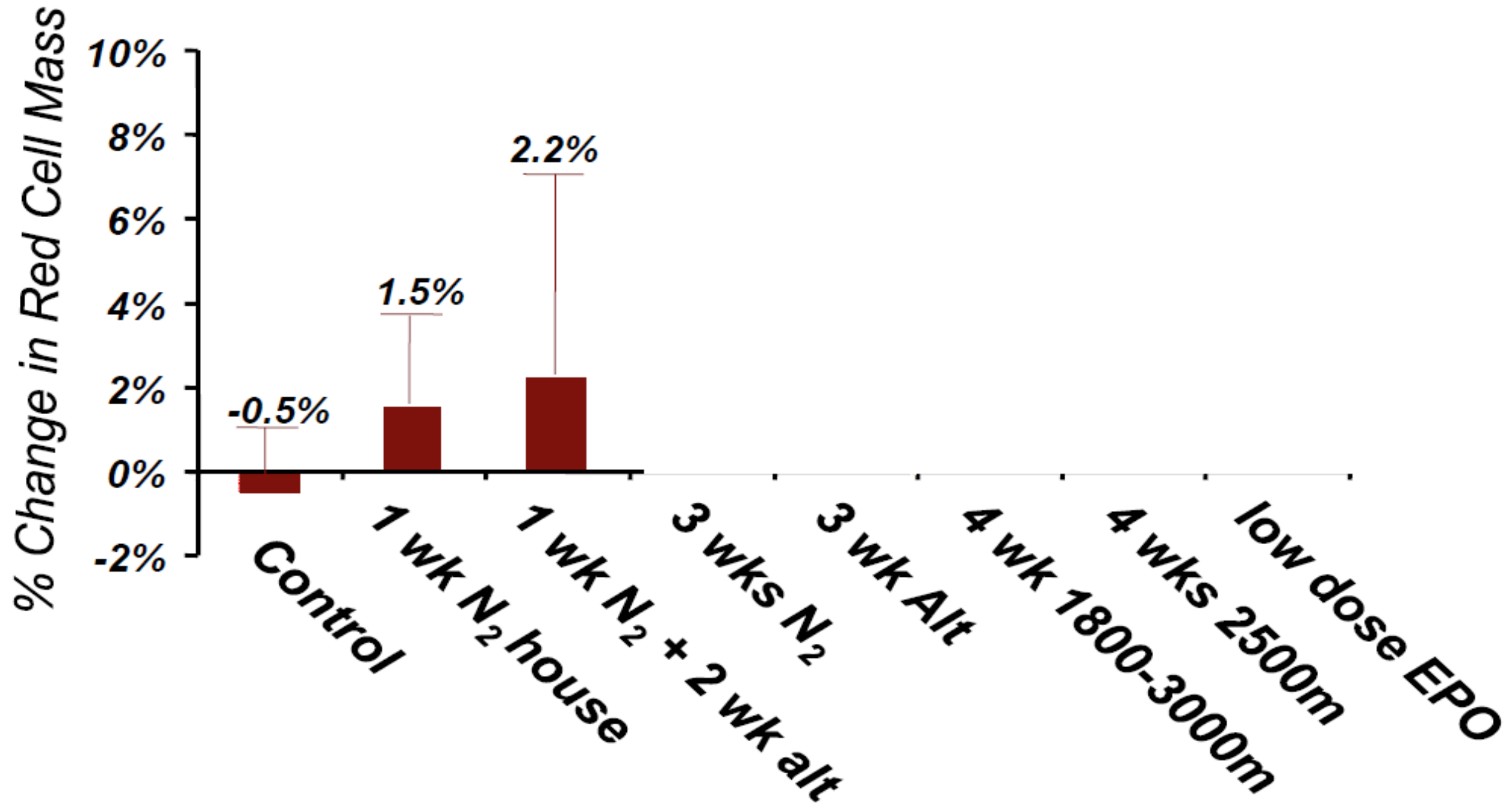
Periodization in the yearly program

From endurance athletes...

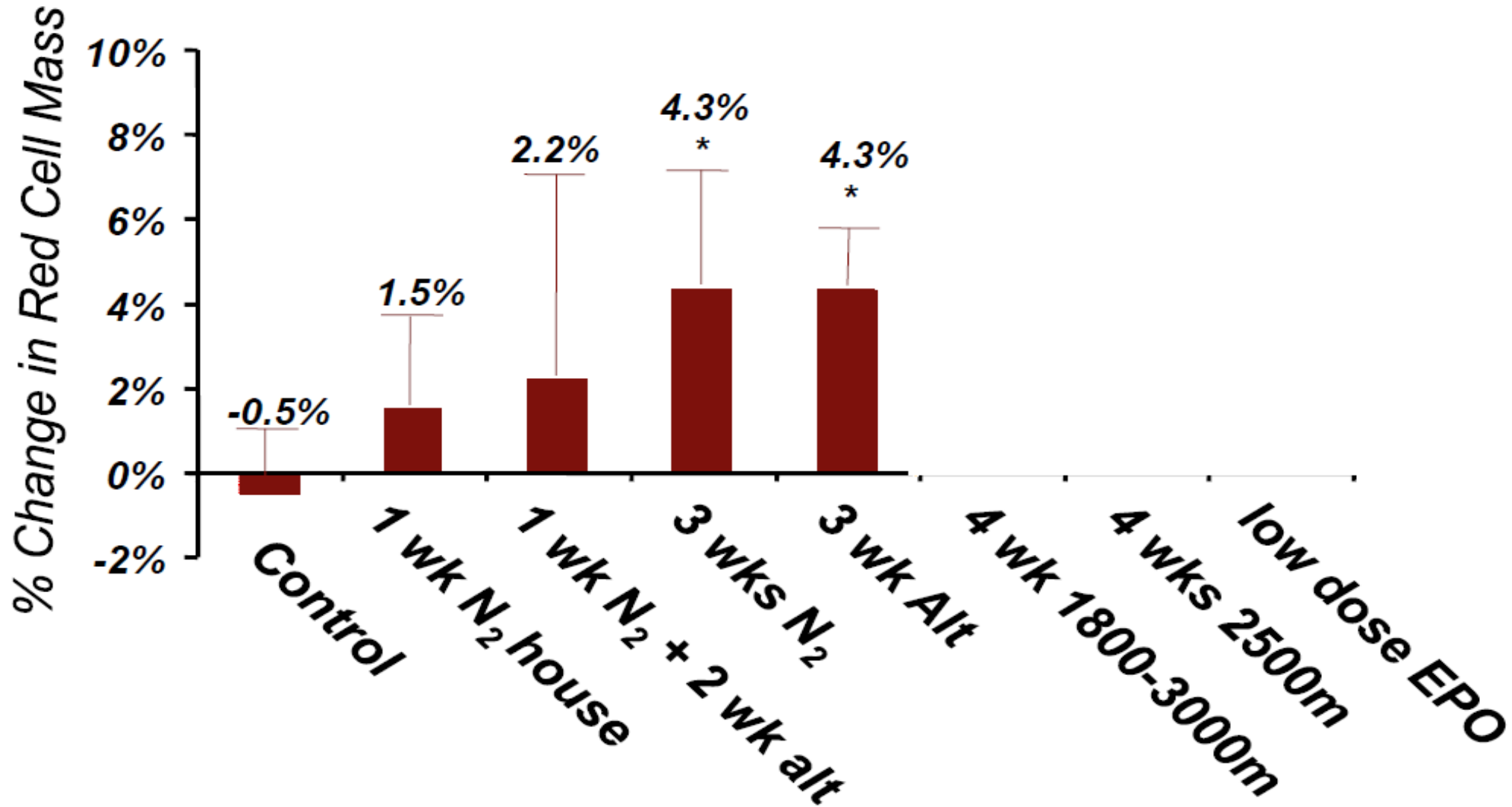




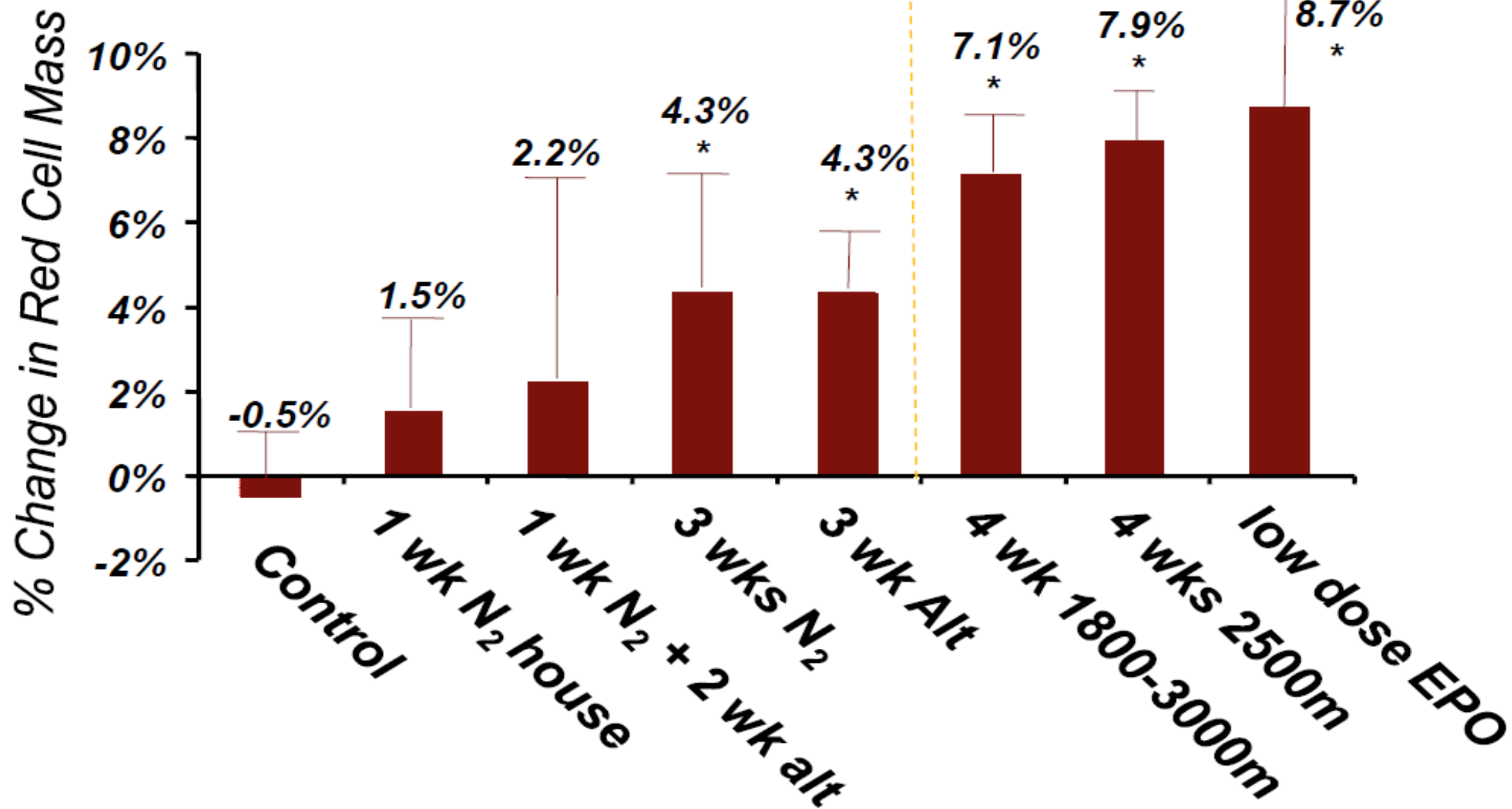




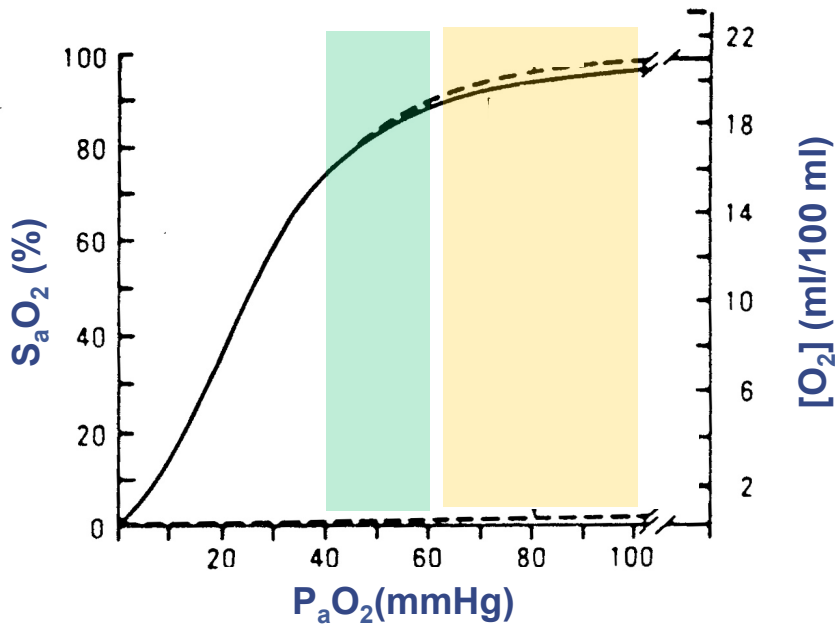
Levine and Stray-Gundersen, 2006



Levine and Stray-Gundersen, 2006



LHTH - Optimal altitude for erythropoiesis ?



oxyhemoglobin dissociation curve

Owing to the flat shape of the oxyhemoglobin dissociation curve above 60 mmHg, changes in P_aO_2 may not have much effect on S_aO_2 .

P_aO_2 values below 60 mmHg are reached from altitudes of about 2500 m (*Anchisi et al., 2001*)

Optimal altitude for LHTH are therefore slightly below this altitude (2200-2500 m) due to the combined effect of altitude- and exercise-induced desaturation (Woorons et al. 2007)

LHTH - Return to sea-level

1. a positive phase (2 to 4 days)
 - hemodilution
 - ventilatory adaptations
2. a negative phase (5-12/15 days) of progressive reestablishment of sea-level training volume and intensity.
 - altered energy cost
 - neuromuscular loss of adaptation
3. a third positive phase (after 15 to 21 days) characterized by a *plateau in fitness*.
 - **increase in O₂ transport**
 - delayed HVR benefits
 - increased economy
4. A **FOURTH** negative phase (30-35 days) ?
(Bonetti and Hopkins 2009 ; Issurin 2007)

LHTH

Why ?

Erythropoiesis

Increase in Hb and red blood cell mass

How ?

Altitude : > 1800 - 2200 – 2500 m

Duration : min 3-weeks. Up to 4 weeks

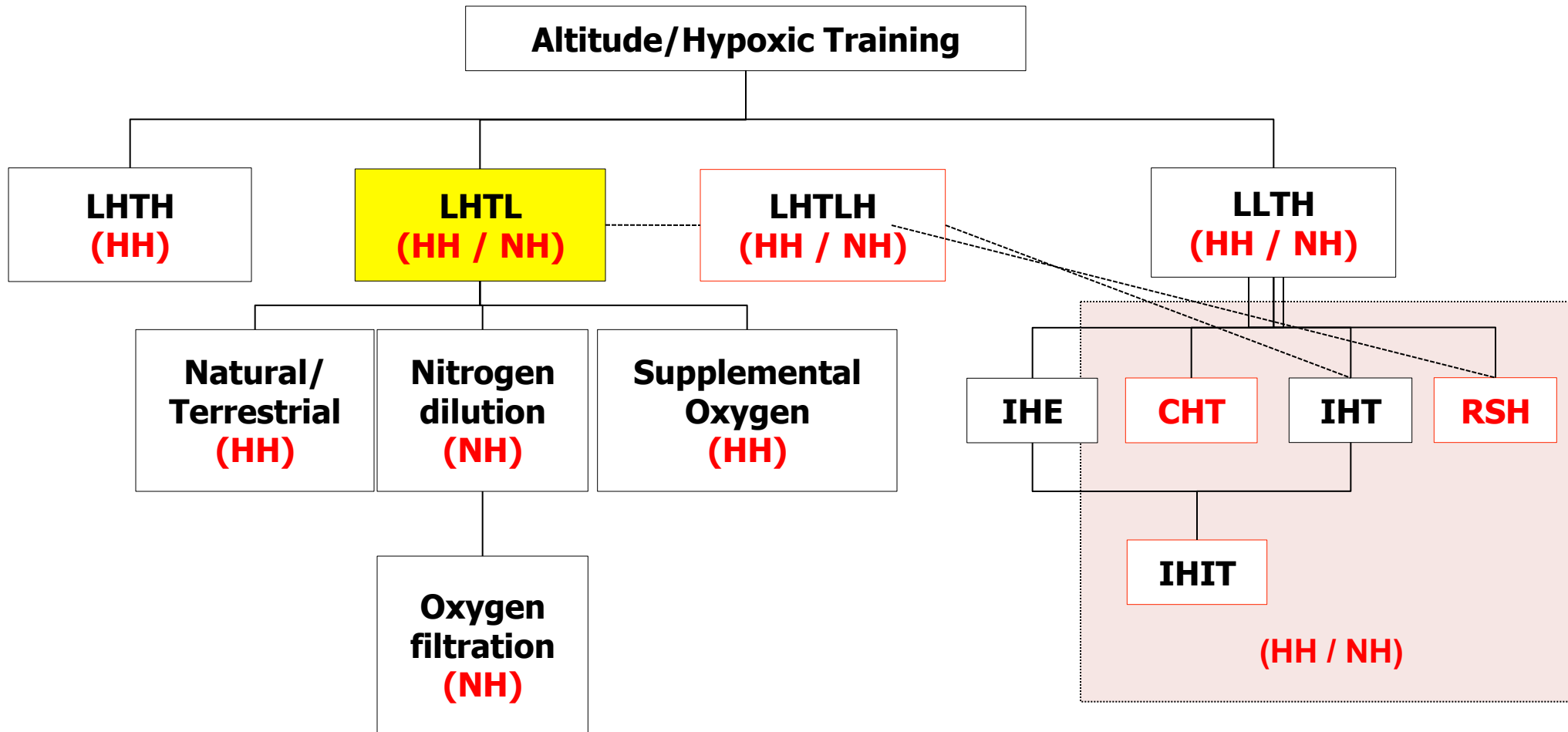
for Who ?

Endurance : 2-4 times a year

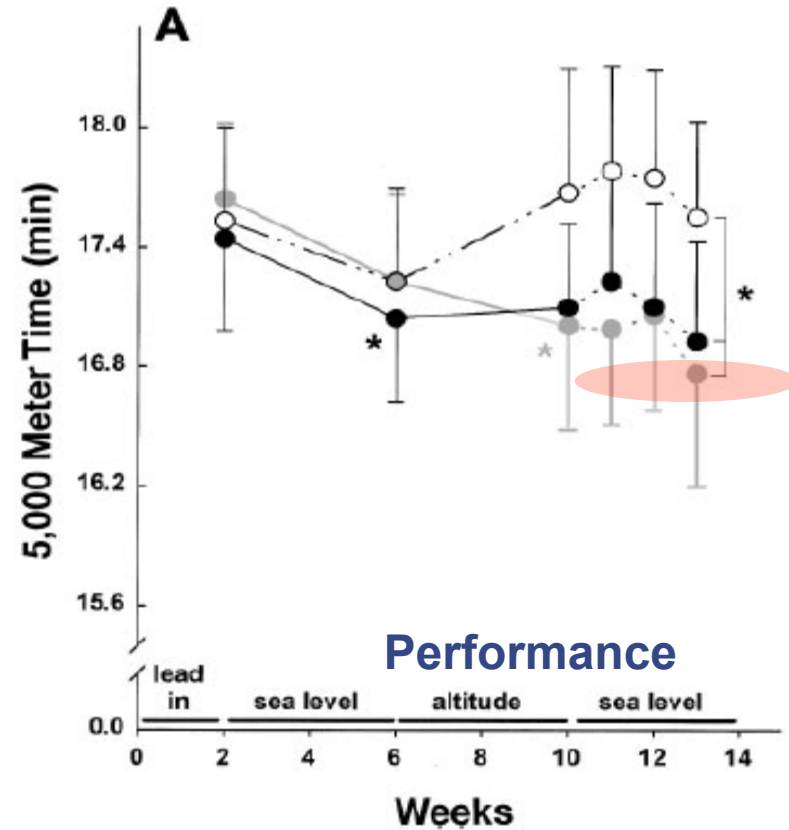
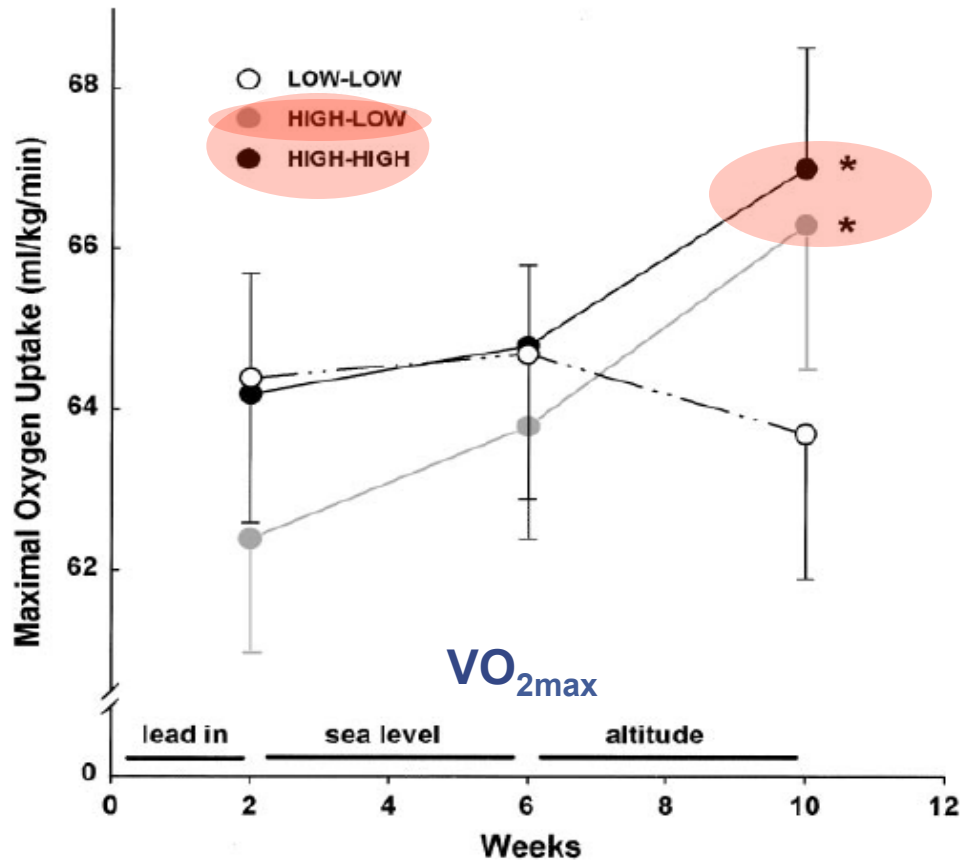
“lactic” : once during winter training

When ?

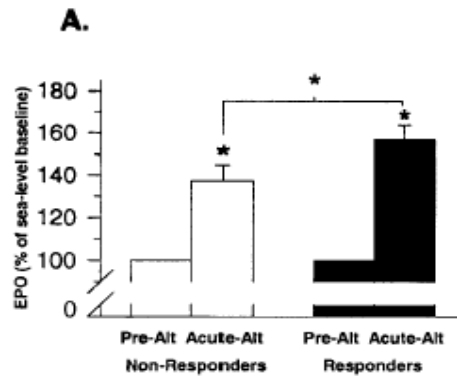
Intermittent: LMTM for general fitness



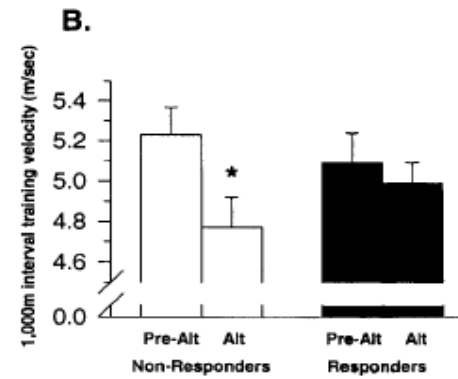
LHTL - Increased VO_{2max} / Improved performance



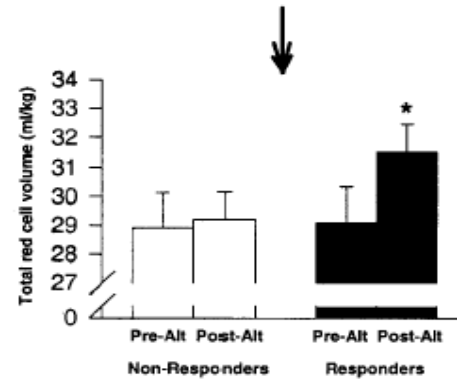
EPO



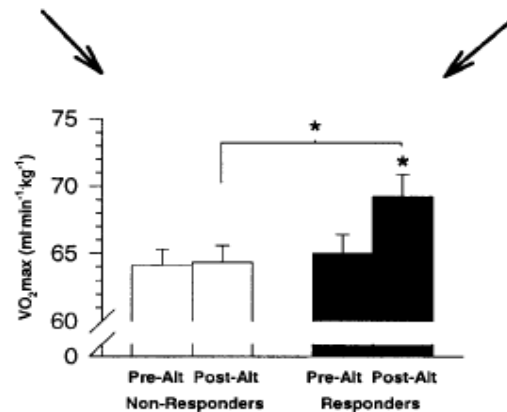
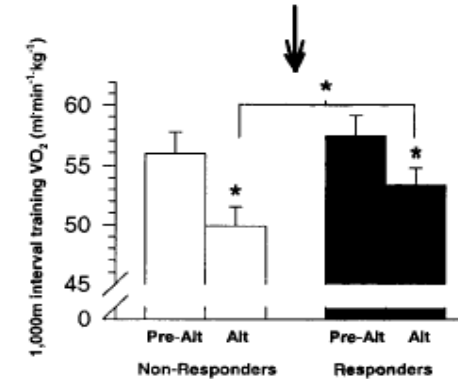
Velocity IT



RCV

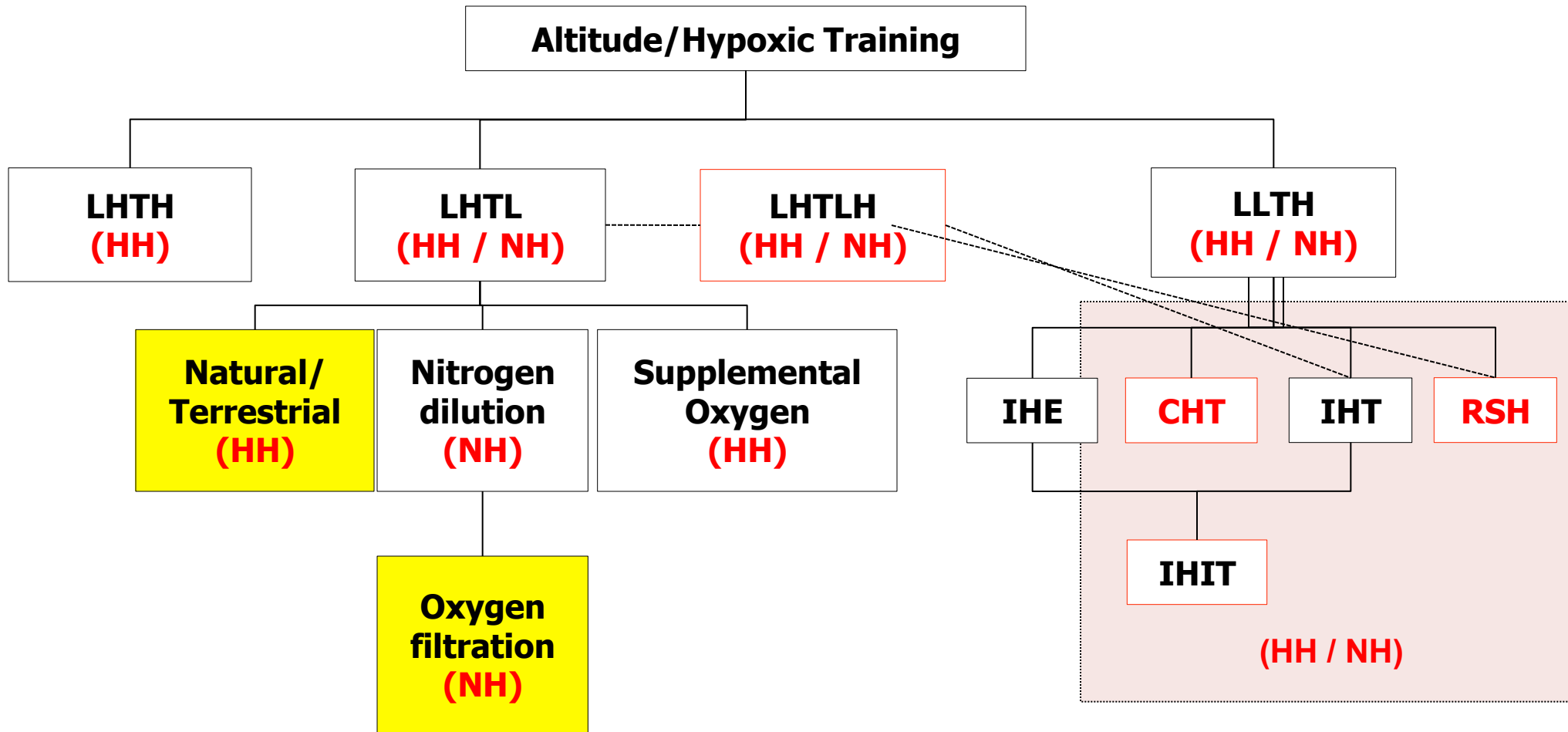


VO₂ IT



VO₂max

(Levine & Stray-Gundersen, 1997)



LHTL – HH vs NH

NH: Prémanon

1200m

F_iO_2 : $15.8 \pm 0.8\%$

BP: 664.9 ± 6.7 mmHg

$P_iO_2 = 121.4 \pm 4.9$

Same P_iO_2

HH: Fiescheralp

2250m

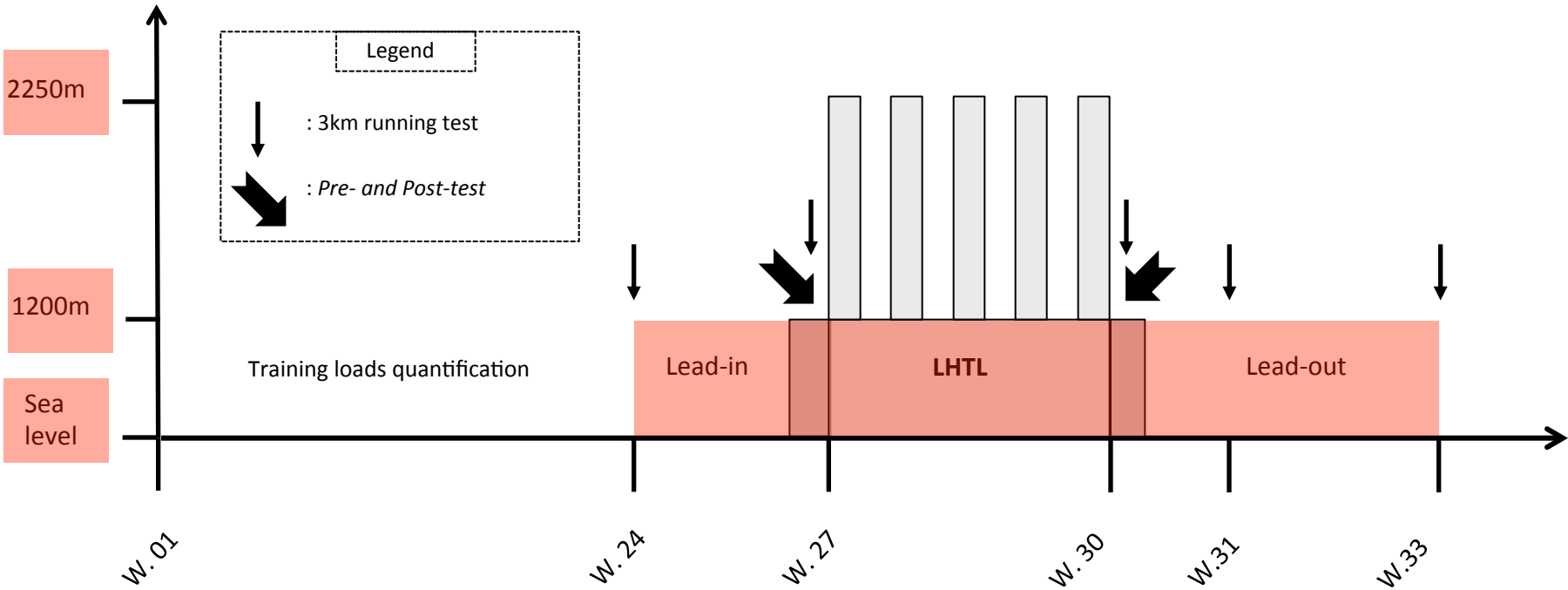
F_iO_2 : $20.93 \pm 0.03\%$

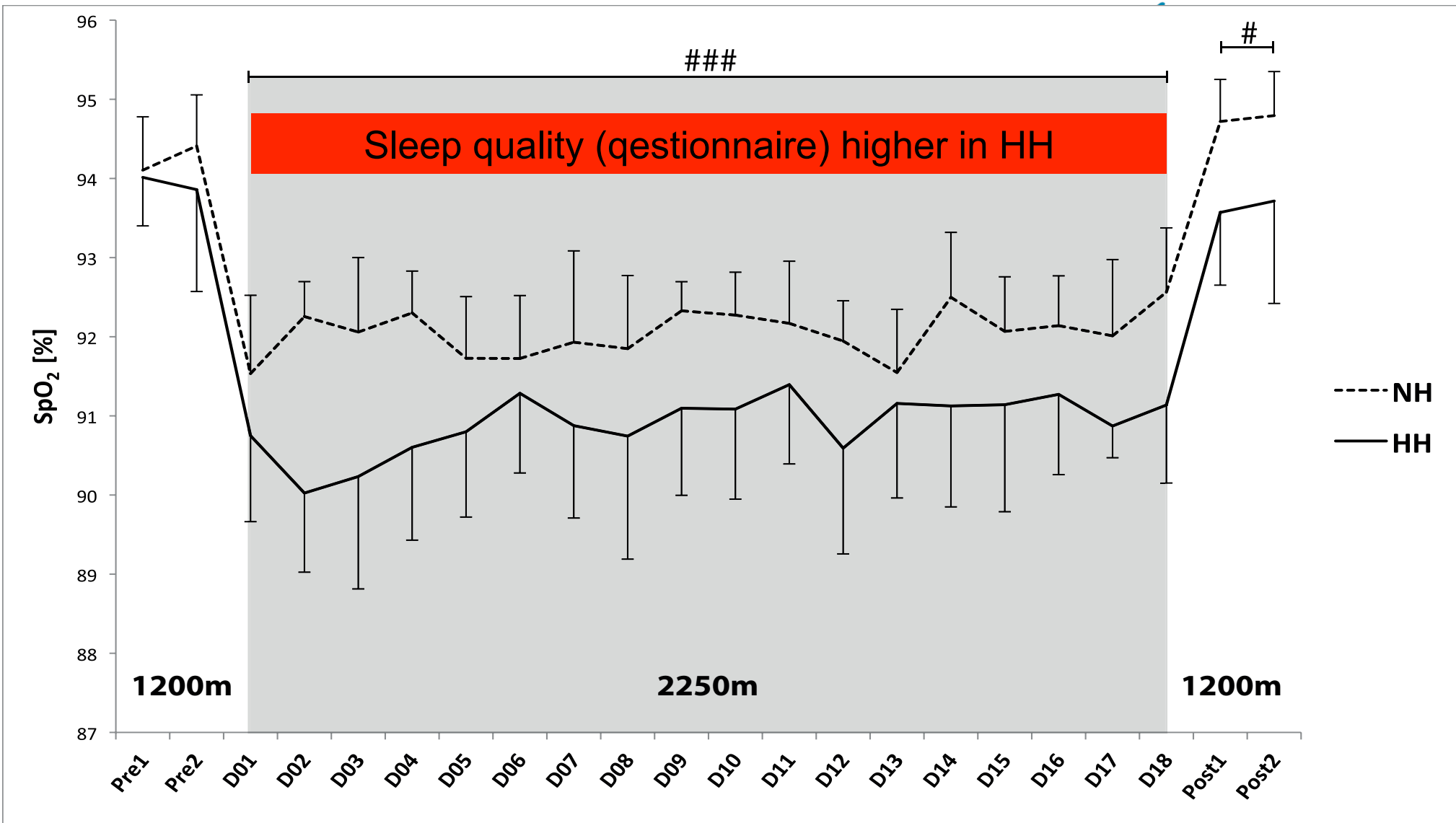
BP: 579.7 ± 23.4 mmHg

$P_iO_2 = 121.3 \pm 4.8$



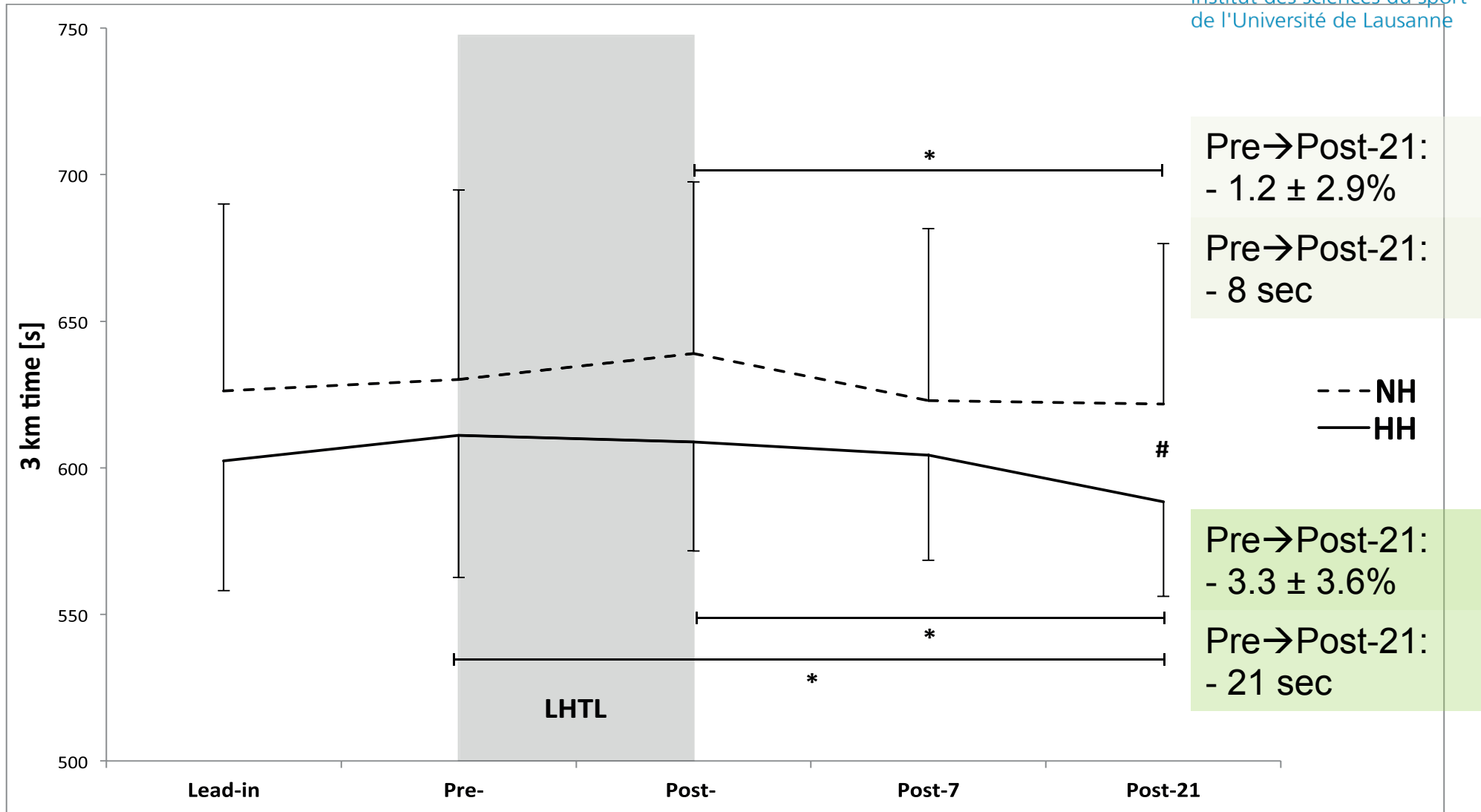
LHTL – HH vs NH





Night SpO₂

(Saugy et al., 2014)



Performance

LHTL

Augmented red cell volume vs non-hematological factors

Economy (*Schmitt et al., 2006*)

Muscle buffering capacity (*Gore et al., 2001*)

Hypoxic ventilatory response (*Townsend et al., 2002*)

Performance increase by 1-3% vs. similar sea-level training.

Why ?

Altitude - HH (terrestrial) > NH (simulated)

2200 – 2500 m for erythropoietic effect (terrestrial)

Up to 3000 m for non-hematological factors (*Brugniaux et al. 2006*)

Duration

4 wks for inducing accelerated erythropoiesis (*Ge et al., 2002*)

2 wks enough for non-hematological factors (*Gore et al., 2001*)

Hypoxic daily dose

Beyond 16 h.day for erythropoietic effect (*Wilber, 2007*)

Shorter (?) for non-hematological changes.

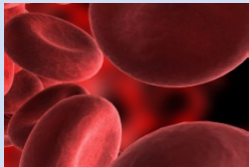



For Who ?

All

When ?

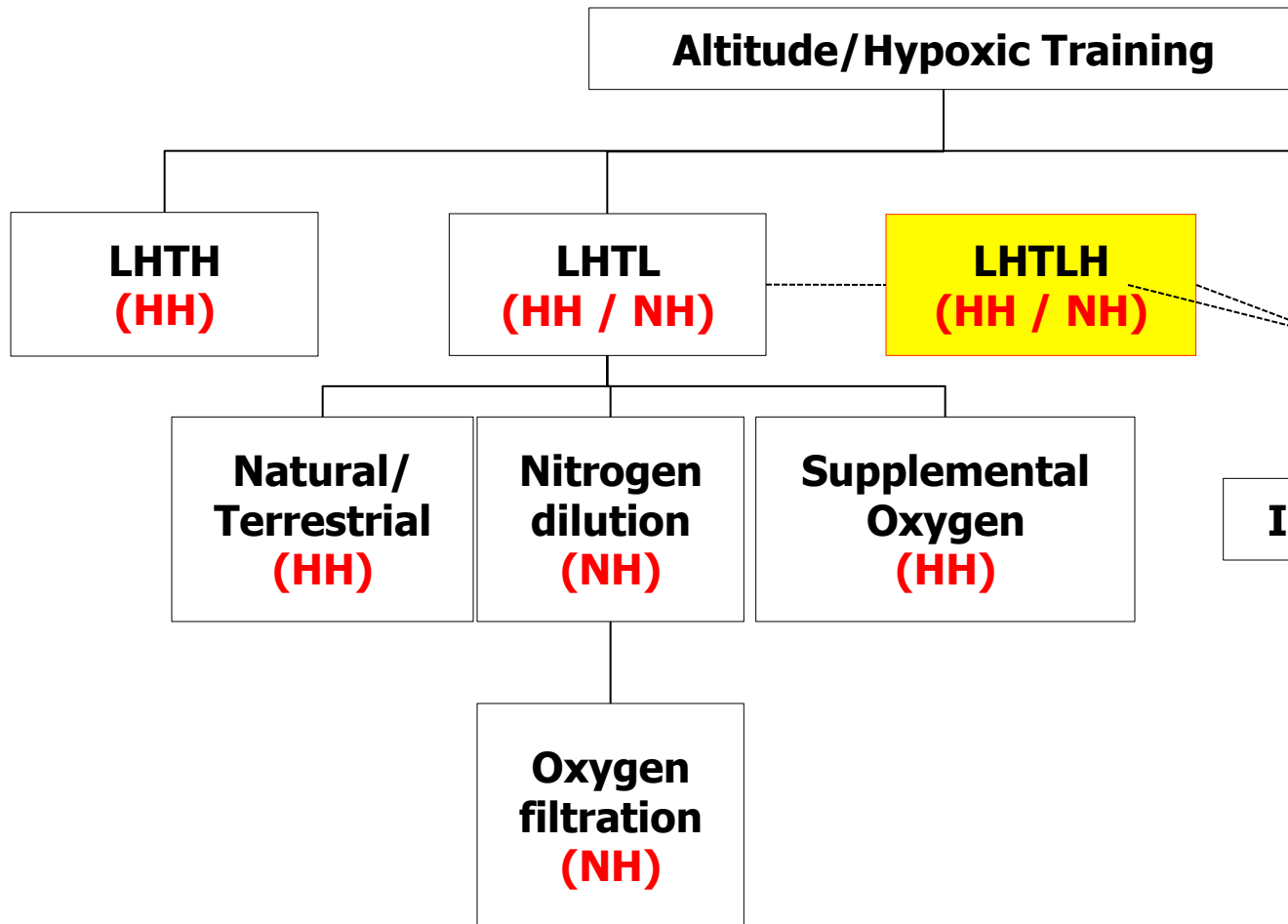
Prior the major competitions

Variability of responses

	Physiological Adaptations		Performance	
	 Hb _{mass}	 4mM speed	 2K/VO _{2max}	 Comp/TT
Multiple 2-wk altitude (swimmers, <math><10\text{h}\cdot\text{d}^{-1}</math>)	0.9%	0.9%	1.2%	-0.4%
Repeated 3-wk LHTL (runners, $14\text{h}\cdot\text{d}^{-1}$)	1 st 2.8%	6.5%	2.1%	-1.4%
	2 nd 2.7%	1.6%	2.1%	0.7%
Extended 6-wk LHTL (runners, $14\text{h}\cdot\text{d}^{-1}$)	4.0%	1.2%	4.3%	-0.3%
Combined LHTL+TH (runners, $14\text{h}\cdot\text{d}^{-1} + \text{TH}$)	3.6%	2.8%	4.8%	-1.1%
3-wk TH (runners, TH $4\cdot\text{wk}^{-1}$)	-0.7%	0.4%	2.2%	-0.1%

to team sport players...





... and patients...





Adipose Tissue Hypoxia

Reduced oxygen tension in tissue in obese patients (Ye 2009)

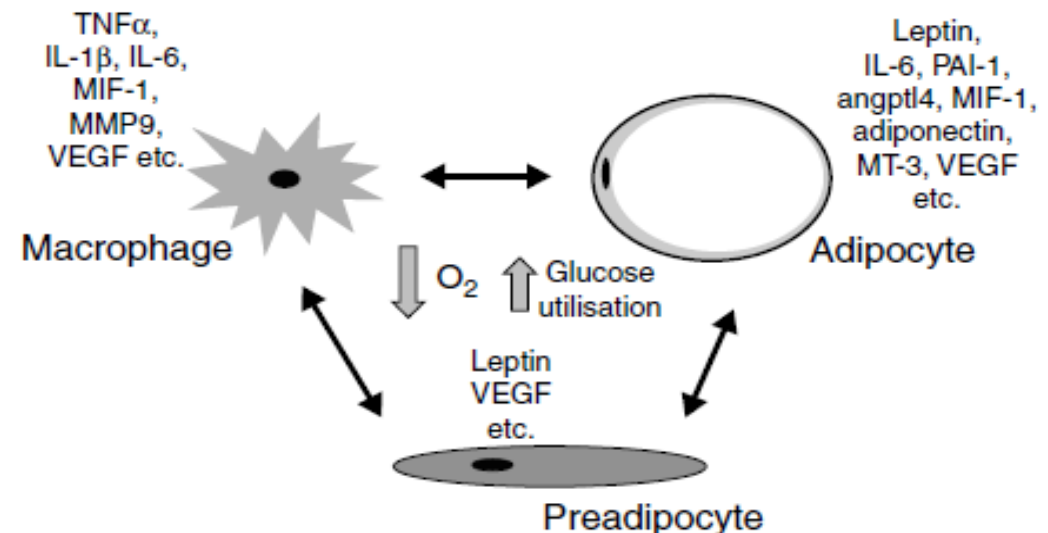
HIF-1 α is increased in the adipose tissue of obese patients and its expression was reduced after surgery-induced weight loss (Semenza 2002)

Angiogenesis deficient in adipose tissue of obese mice: VEGF expression not increased (Ye 2004).

H-induced inflammation

Obesity induces a chronic low-grade inflammatory state.

H induces gene expression in adipocytes and macrophages (Wood 2009)



Compensatory adaptations to Hypoxic exposure or exercise

Respiratory system	Cardiovascular system	Cellular and metabolic	Regulation of body weight
<p>Hyperventilation</p> <p>↑ lung diffusion capacity</p> <p>↑ CO₂ reserve in sleeping</p> <p>↓ Sleep desaturation</p> <p>↑ ventilatory response during exercise</p> <p>Improves respiratory function</p>	<p>↑ basal and max HR</p> <p>↑ peripheral vasodilation</p> <p>↑ VO_{2max}</p> <p>↓ Pro-inflammatory factors</p> <p>Cardiovascular protection</p>	<p>↑ HIF-1 and VEGF</p> <p>↑ Angiogenesis</p> <p>↑ diameter of arterioles</p> <p>↑ glycolytic enzymes & mitochondria</p> <p>↑ Hb-O₂ affinity</p> <p>↑ O₂, Fe and glucose conveyors</p> <p>Improves insulin sensitivity</p> <p>↑ glucose transporter GLUT-4</p>	<p>↓ basal leptin levels</p> <p>↑ adrenergic system</p> <p>Basal noradrenaline remains high post-treatment</p> <p>↑ blood serotonin levels</p> <p>↓ Appetite</p> <p>↑ body weight loss</p>



Compensatory adaptations to Hypoxic exposure or exercise

Brain	Cardiovascular system
<p>↑ vasoreactivity</p> <p>↑ cerebral blood flow and oxygenation</p> <p>↓ desaturation</p> <p>Improves cerebral function</p>	<p>↓ hypertension NO inactivation</p> <p>↑ release vasodilators (NO/NOS pathway)</p> <p>↑ circulating angiogenic factors</p> <p>↑ peripheral vasodilation</p> <p>↓ Arterial stiffness</p> <p>↓ Pro-inflammatory factors</p> <p>Oxidative stress modulation</p> <p>↑ exercise-induced Hypoxemia – compensatory vasodilation</p> <p>Normalises blood pressure</p>

Thank you

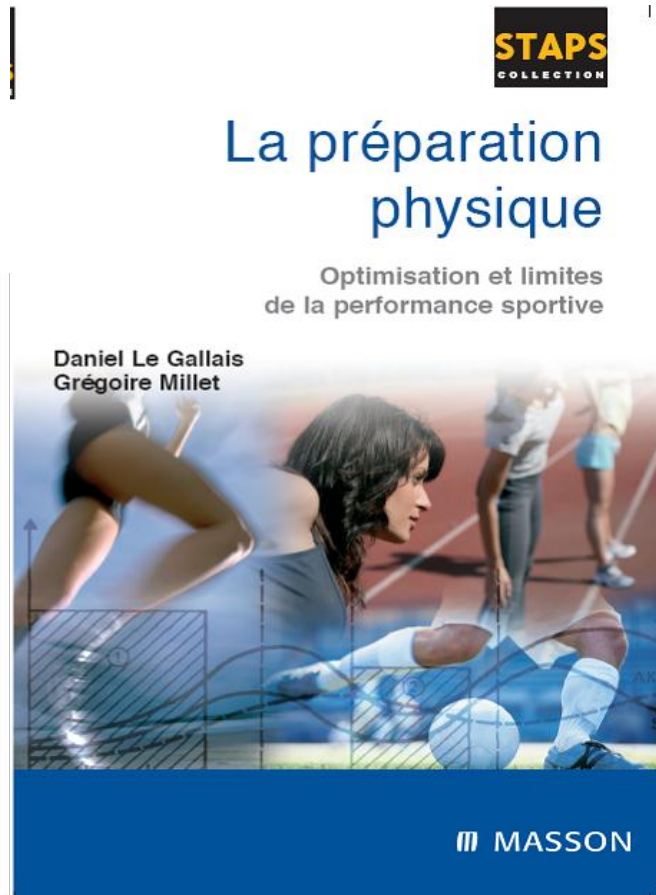


Any Questions ?

Few steps beyond..

La préparation physique.

D. Legallais & G. Millet
2007, Masson



S'entraîner en altitude

G. Millet & L. Schmitt
2011, deBoeck Univ



L'endurance.

Millet G. (ed), 2006
Edition EPS

