Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Effect of training and altitude training on haemoglobin mass and performance:

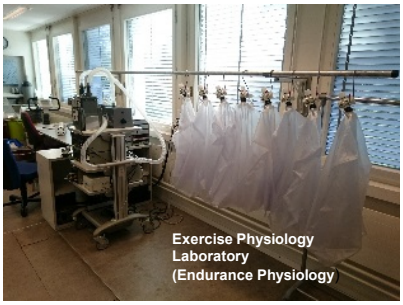
How can we legally increase haemoglobin mass in elite endurance athletes?

Jon Peter Wehrlin, PhD

Head Endurance Physiolgy Group, Section for Elite Sport

Swiss Federal Institute of Sports, Magglingen, Switzerland

Section for Elite Sport Laboratories

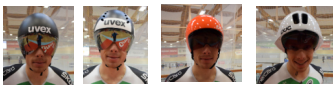


Research & Development

Applied Research

Goal: Answer applied research questions (ideally from the athletes and coaches) to improve performance….

Mountainbike: What is faster 26 or 29inch wheel?



Track cycling: Which helmet is the best for my athlete?

Effect of precooling on performance in the Tokyo heat?

Can my athlete profite from altitude training?

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

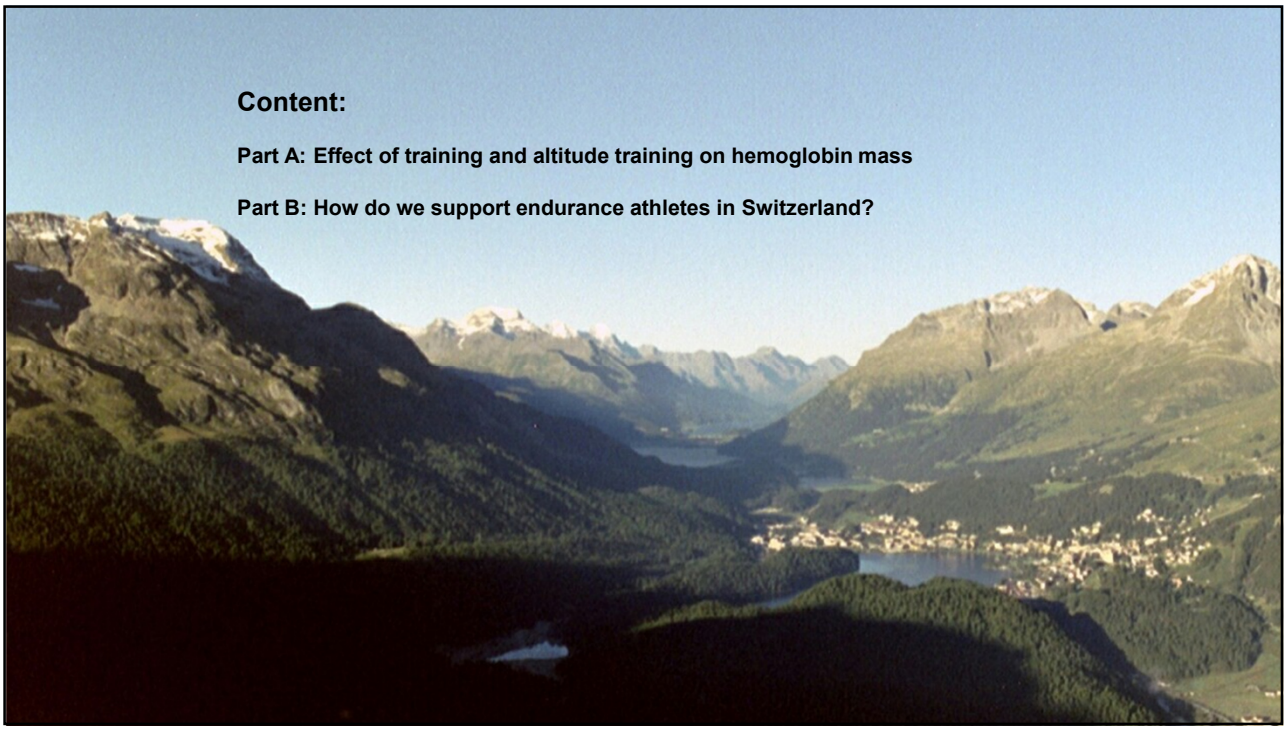
Effect of training and altitude training on haemoglobin mass and performance:

How can we legally increase haemoglobin mass in elite endurance athletes?

Jon Peter Wehrlin, PhD

Head Endurance Physiolgy Group, Section for Elite Sport

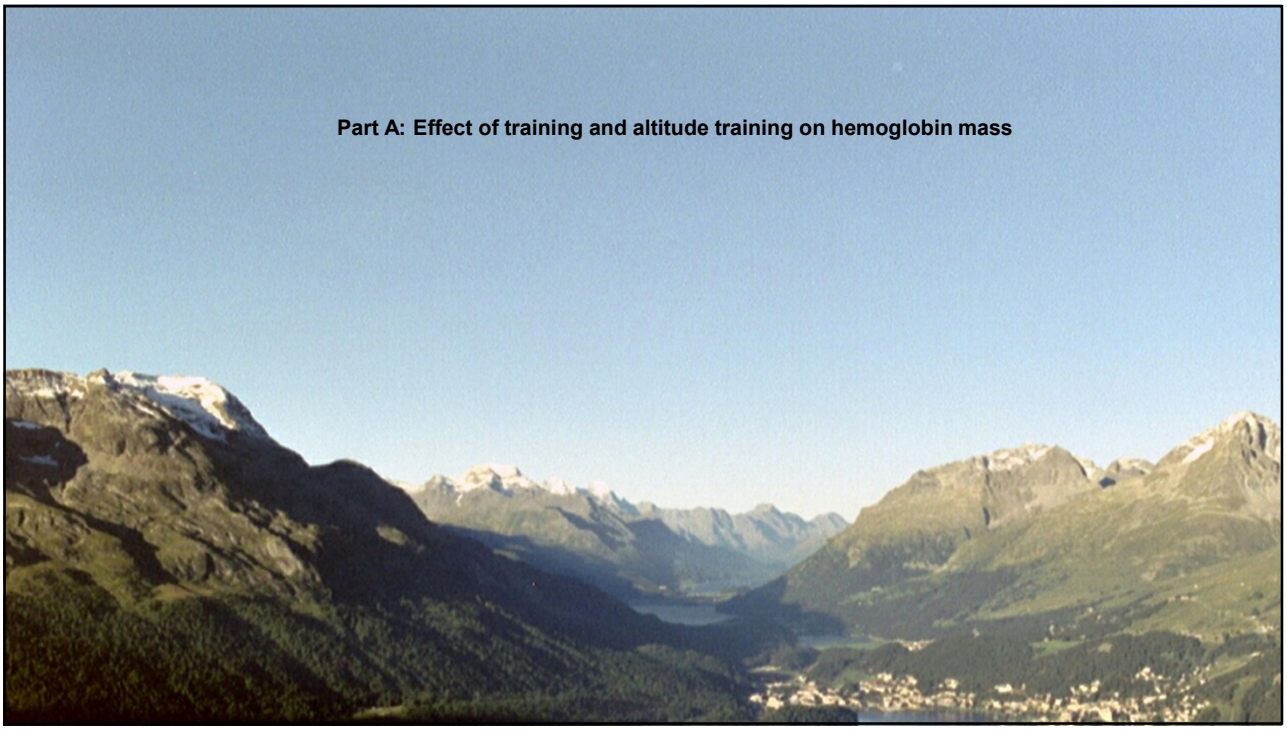
Swiss Federal Institute of Sports, Magglingen, Switzerland



Content:

Part A: Effect of training and altitude training on hemoglobin mass

Part B: How do we support endurance athletes in Switzerland?



Part A: Effect of training and altitude training on hemoglobin mass

Endurance sport: VO_{2max} - Important limiting factors

Ventilation & Lung diffusion capacity

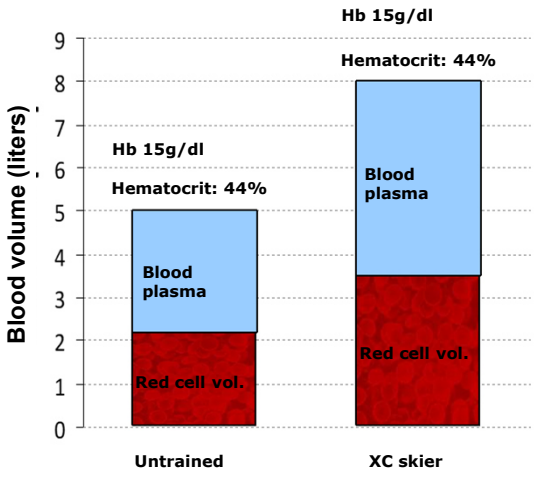
Heart capacity

Oxygen transport capacity

Muscle capacity

Bassett DR and Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sports Exerc*. 2000; 32: 70-84.

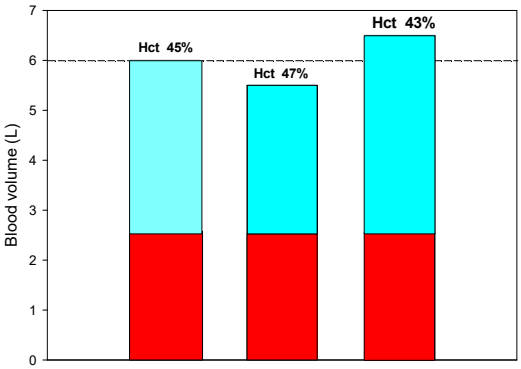
Introduction: Physiological effects and adaptations to moderate altitude



Problem: We do not know how the absolute values are!

Introduction: Physiological effects and adaptations to moderate altitude

Hb (g/dl) and Hct (%): Effects of changes in plasma volume

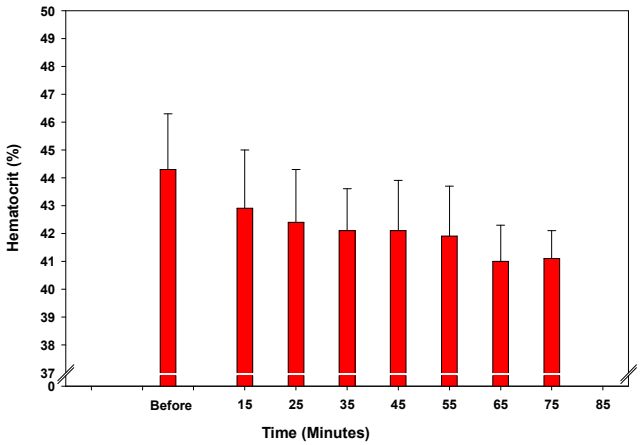


Important factors:

- **Position: (horizontal = ↓ vs vertical = Hct ↑**
- **Hydratation status (low = Hct ↑; high ↓)**
- **Training (acute = Hct ↑; after = Hct ↓)**
- **Altitude: (acute = Hct ↑)**
- **Heat: (acute = Hct ↑; chronic↓)**

Introduction: Problem with hematocrit and hemoglobin (g/dl)

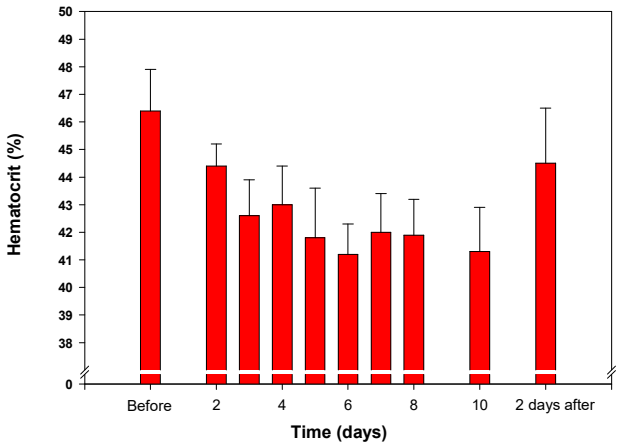
Effect of drinking one liter of saline solution on hematocrit value



Modified after Schmidt W. et al. Int J Sports Med, 21: 133-138; 2000

Introduction: Problem with hematocrit and hemoglobin (g/dl)

=> Effect of a ten days cycling competition on hematocrit value (identical withHb g/dl)



Modified after Schmidt W. et al. Int J Sports Med, 21: 133-138; 2000

Introduction: Physiological effects and adaptations to moderate altitude

Blood basics

=> Important to measure absolute values!

Blood volume:
8000 ml

Hemoglobin mass:
1256 g

Red cell volume:
3520 ml

Plasma volume:
4480 ml

Introduction: Physiological effects and adaptations to moderate altitude

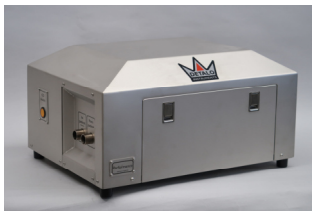
CO-rebreathing method (100 years):

- Revived by Fogh-Andersen et al. (1990) and Thomsen et al. (1991) and is now frequently used in Sports Science and Sports Medicine:

- "Optimized method" by Schmidt and Prommer (2005)

- with minor modifications (Prommer & Schmidt 2007)

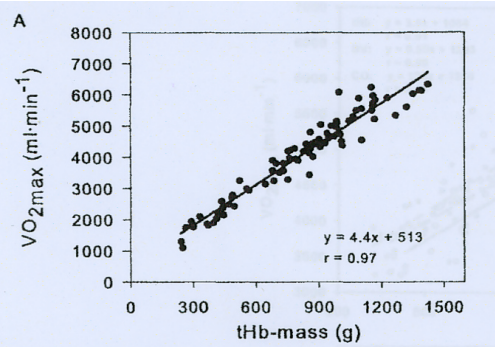
Meta-Analysis about Error Measurement for blood volume paramters (Gore et al. 2005):
=> CO-rebreathing-method has the lowest error

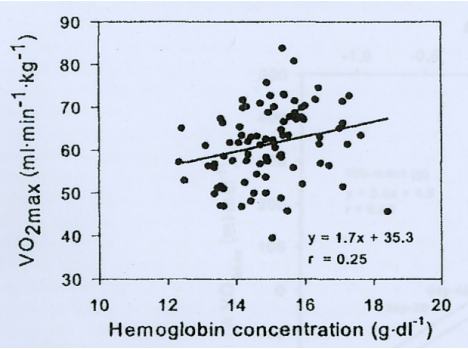


	Hb_{mass}	RCV	PV	BV
CV	1.37%	1.89%	2.62%	1.86%
R	0.991	0.981	0.968	0.980
Range	822-1264 g	2161-3456 ml	3185 – 5740 ml	5610 – 9197 ml

Values from our Laboratory, (n=17)

Introduction: Physiological effects and adaptations to moderate altitude





Schmidt & Prommer Exerc Sport Sci Rev, 2010

Endurance Sport: Problem «Blood Doping»

Stray-Gundersen J, Videman T, Penttilä L, Lereim I; Abnormal hematologic profiles in elite cross-country Skiers: blood doping or? Clin J Sports Med, 2003, 132-7

Importance of the hemoglobin mass: Blood doping

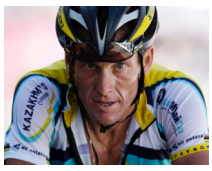
Switzerland


SPORT

Gedopter Thomas Frei erklärt, wie er die Kontrolleure jeweils täuschte

Spain

USA

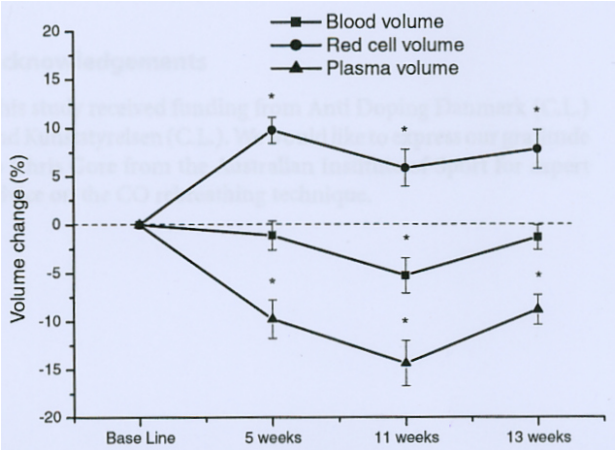


Denmark

…..etc.

Importance of the hemoglobin mass:

=> Blood doping with rhEPO



Lundby et al., J Physiol, 2007

Importance of the hemoglobin mass:

=> Problem: Blood doping with low volume autologous blood transfusion

Nordic World Ski Championships 2019: Max Hauke (Austria)

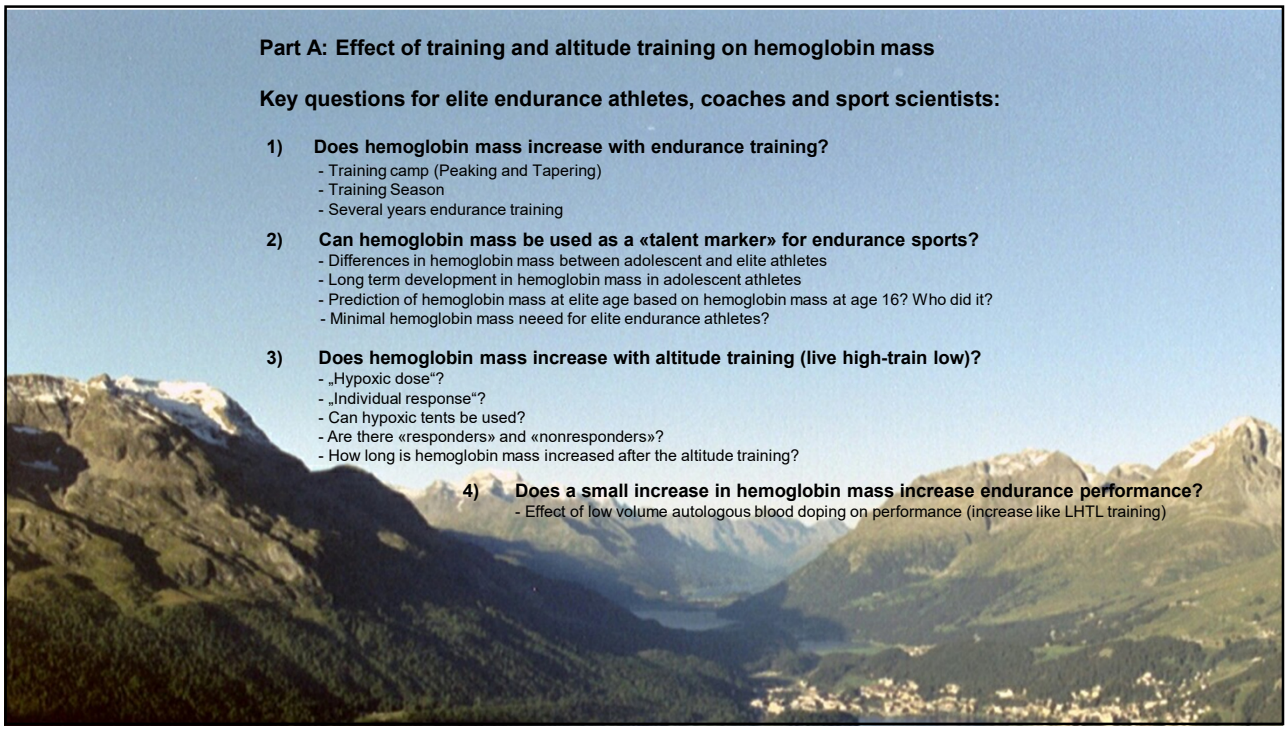
135ml RBC =300ml Blood (Hct 45%)

Hct 45% = Hb 15g/dl

3dl Blood * 15g/dl = 45g Hemoglobin

If the Athlete has 1000g hemoglobin mass

⇒ 45g = 4.5% increase in Hemoglobin mass



Part A: Effect of training and altitude training on hemoglobin mass

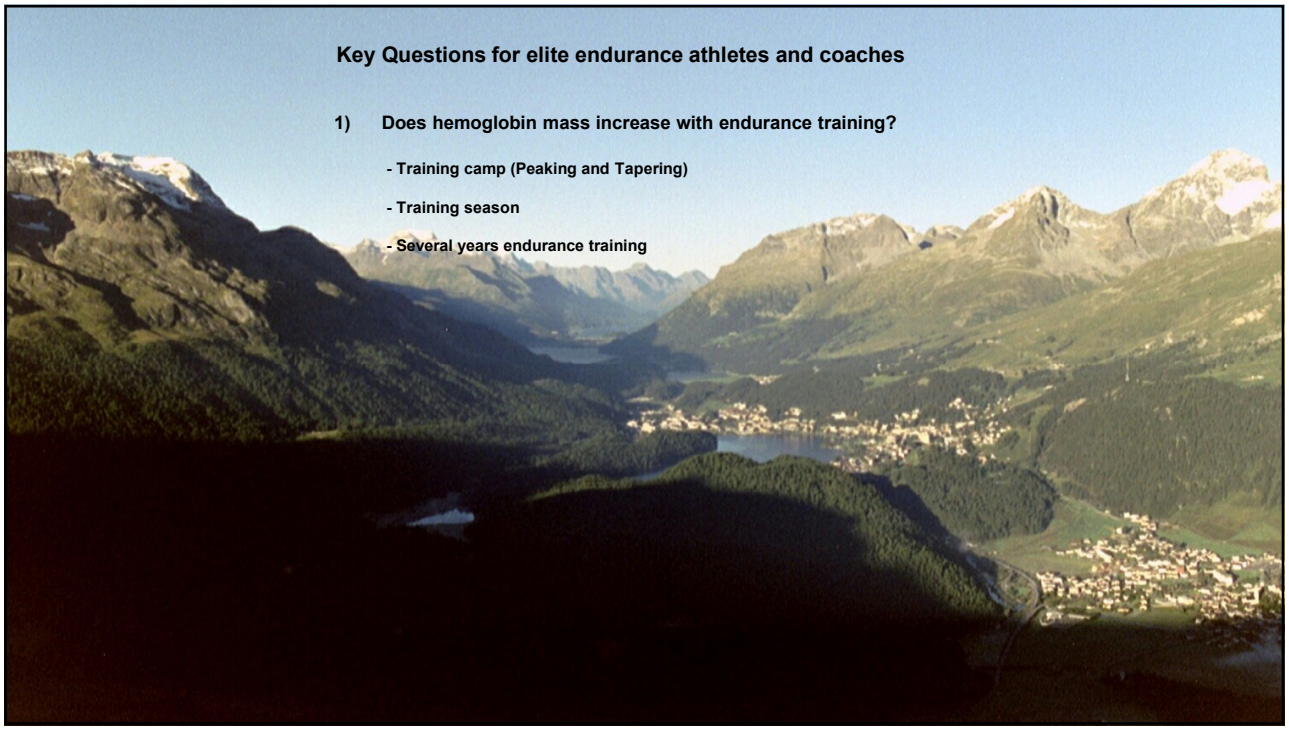
Key questions for elite endurance athletes, coaches and sport scientists:

1) **Does hemoglobin mass increase with endurance training?**
   - Training camp (Peaking and Tapering)
   - Training Season
   - Several years endurance training

2) **Can hemoglobin mass be used as a «talent marker» for endurance sports?**
   - Differences in hemoglobin mass between adolescent and elite athletes
   - Long term development in hemoglobin mass in adolescent athletes
   - Prediction of hemoglobin mass at elite age based on hemoglobin mass at age 16? Who did it?
   - Minimal hemoglobin mass neeed for elite endurance athletes?

3) **Does hemoglobin mass increase with altitude training (live high-train low)?**
   - „Hypoxic dose“?
   - „Individual response“?
   - Can hypoxic tents be used?
   - Are there «responders» and «nonresponders»?
   - How long is hemoglobin mass increased after the altitude training?

4) **Does a small increase in hemoglobin mass increase endurance performance?**
   - Effect of low volume autologous blood doping on performance (increase like LHTL training)



Key Questions for elite endurance athletes and coaches

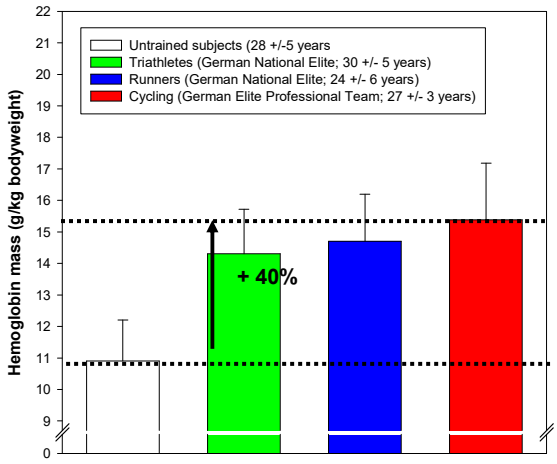
1) **Does hemoglobin mass increase with endurance training?**

   - Training camp (Peaking and Tapering)

   - Training season

   - Several years endurance training

1) Does hemoglobin mass increase with normal training?



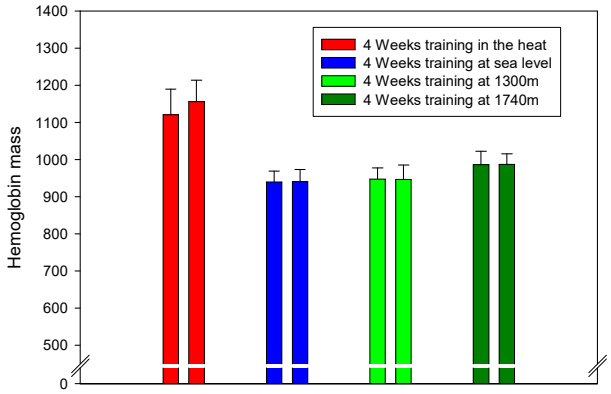
Key question:

Effect of „training“ or„talent“?

Modified after Heinicke et al. Int J Sports Med, 2001

1) Does hemoglobin mass increase with normal training?

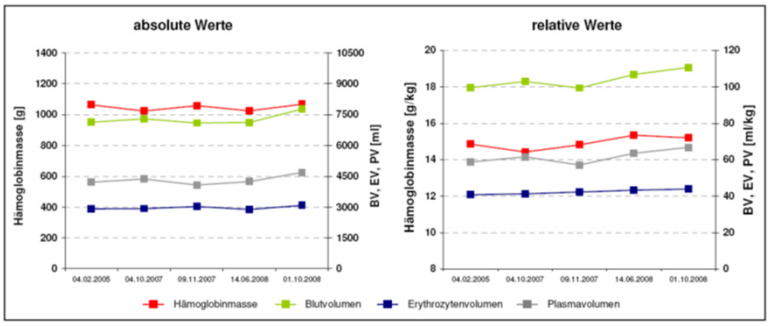
=> Changes during a training camp



Modified after Gore et al., Int J Sports Med, 1997

Does hemoglobin mass increase with normal training?

=> Several years of endurance training

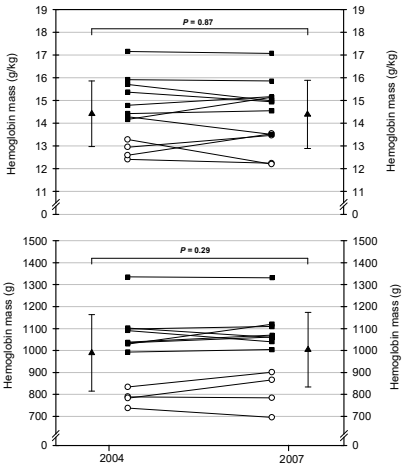


⇒ **Observation in routine hemoglobin mass measurement:**
Elite athletes show no big changes in hemoglobin mass with normal training

⇒ **Possible to use it as "talent identification marker" in adolesence?**

Does hemoglobin mass increase with normal training?

=> Changes with several years of training

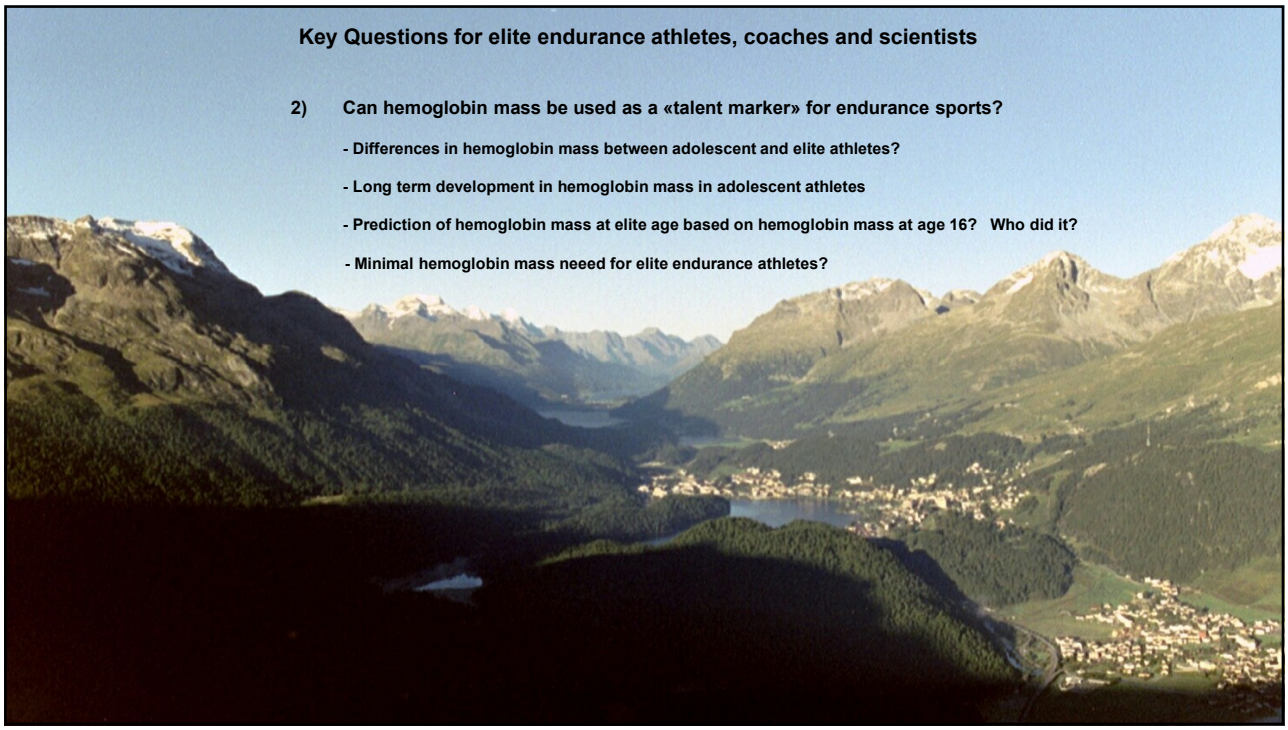


Wehrlin, J.P., Hallén J. Marti B. Adv Exp Med Biol. 2016;903:357-74.

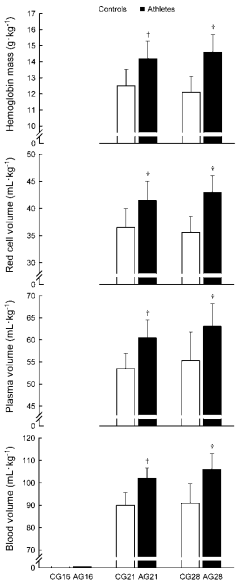
Key Questions for elite endurance athletes, coaches and scientists

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

- **Differences in hemoglobin mass between adolescent and elite athletes?**
- **Long term development in hemoglobin mass in adolescent athletes**
- **Prediction of hemoglobin mass at elite age based on hemoglobin mass at age 16? Who did it?**
- **Minimal hemoglobin mass neeed for elite endurance athletes?**



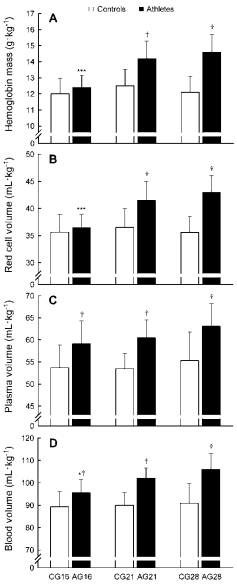
2) Can hemoglobin mass be used as a «talent marker» for endurance sports?



=> Differences in hemoglobin mass between adolescent and elite national team athletes?

Steiner & Wehrlin. Med Sci Sports & Exercise, 2011

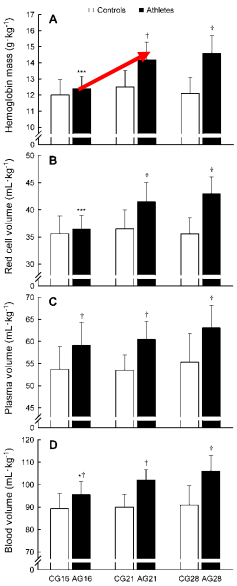
2) Can hemoglobin mass be used as a «talent marker» for endurance sports?



=> Differences in hemoglobin mass between adolescent and elite athletes?

Steiner & Wehrlin. Med Sci Sports & Exercise, 2011

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

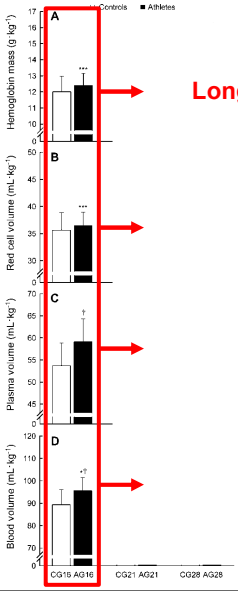


=> Differences in hemoglobin mass between adolescent and elite athletes?

«Golden age» between 16 and 21 to increase hemoglobin mass with endurance training?

Steiner & Wehrlin. Med Sci Sports & Exercise, 2011

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

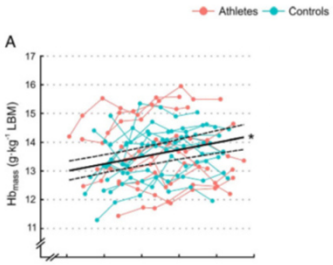


Longitudinal study over 3 years

Steiner & Wehrlin. Med Sci Sports & Exercise, 2011

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

=> Long term develepment of hemoglobin mass in adolescent athletes?

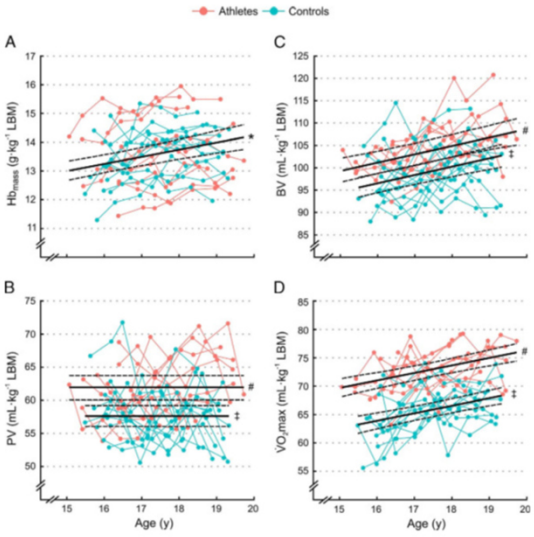


Steiner T, Maier T, Wehrlin JP.
Med Sci Sports Exerc. 2019
May: 51(5):912-919

Age (y) Age (y)

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

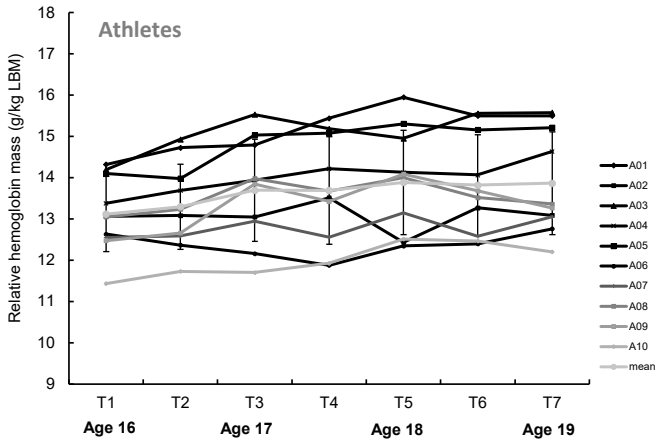
=> Long term develepment of hemoglobin mass in adolescent athletes?



Steiner T, Maier T, Wehrlin JP.
Med Sci Sports Exerc. 2019
May: 51(5):912-919

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

=> Prediction of hemoglobin mass at elite age based on hemoglobin mass at age 16? **Who did it?**



Steiner & Wehrlin. Annual Meeting, Swiss Sport Science Society, 2018

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

=> Prediction of hemoglobin mass at elite age based on hemoglobin mass at age 16? **Who did it?**

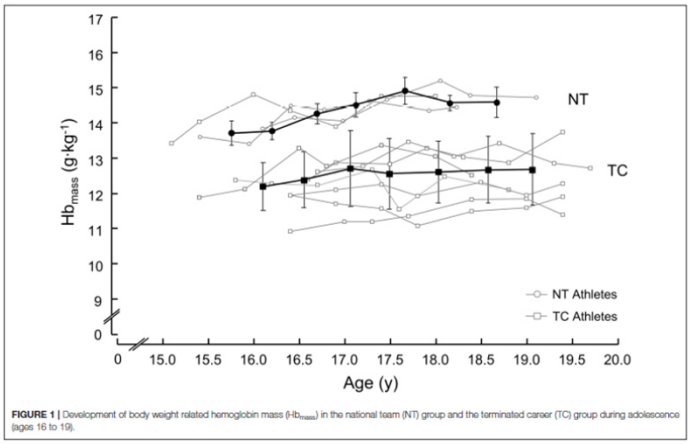
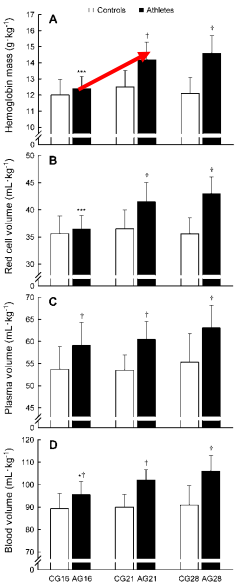


FIGURE 1 | Development of body weight related hemoglobin mass (Hb_{mass}) in the national team (NT) group and the terminated career (TC) group during adolescence (ages 16 to 19).

Citation:
Wehrlin JP and Steiner T (2021) Is Hemoglobin Mass at Age 16 a Predictor for National Team Membership at Age 25 in Cross-Country Skiers and Triathletes? Front. Sports Act. Living 3:580486. doi: 10.3389/fspor.2021.580486

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?



=> Differences in hemoglobin mass between adolescent and elite athletes?

«Golden age» between 16 and 21 to increase hemoglobin mass with endurance training?

=> No, selection bias.

Steiner & Wehrlin. Med Sci Sports & Exercise, 2011

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

=> Minimal hemoglobin mass needed for elite endurance athletes?

Men:	National team:	> 14g/kg bodyweight
	World class:	> 15g - 16g/kg bodyweight
Women:	National team:	> 12 g/kg bodyweight
	World class:	> 13 - 14 g/kg bodyweight

High prediction of hemoglobin mass at at 20 already at age 16!

2) Can hemoglobin mass be used as a «talent marker» for endurance sports?

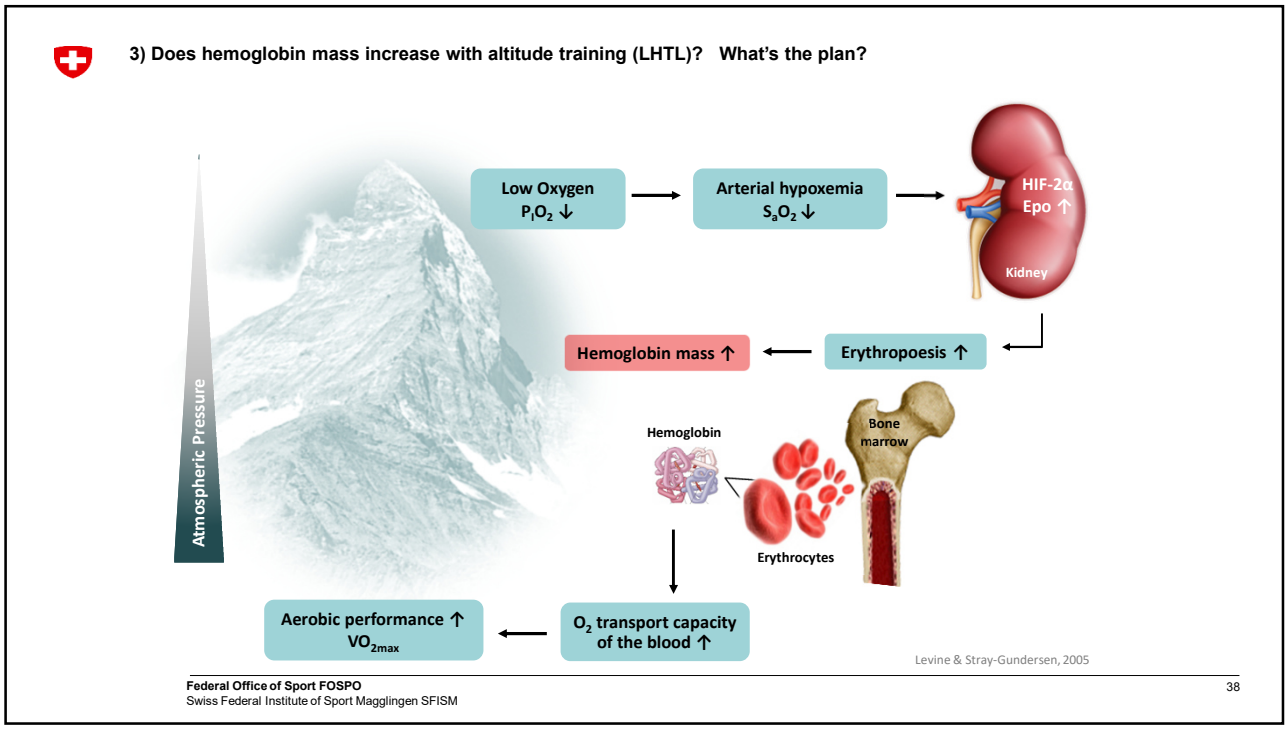
=> Minimal hemoglobin mass needed for elite endurance athletes?

Men:	National team:	> 14g/kg bodyweight
	World class:	> 15g-16g/kg bodyweight
Women:	National team:	> 12g/kg bodyweight
	World class:	> 13-14g/kg bodyweight

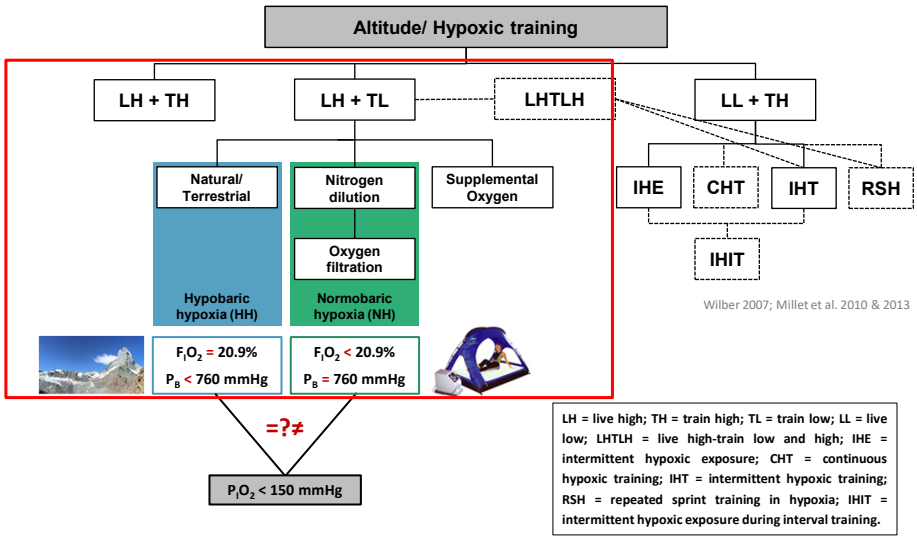
However, we do not systematically use Hb_{mass} for Talent identification – we do not have enough talents!

=> High prediction of hemoglobin mass at at 20 already at age 16!


Key Questions for elite endurance athletes, coaches and scientists
3) Does hemoglobin mass increase with altitude training (LHTL)?
- „Hypoxic dose“?
- „Individual response“?
- Can hypoxic tents be used?
- Are there «responders» and «nonresponders»?
- How long is hemoglobin mass increased after the altitude training?


3) Does hemoglobin mass increase with altitude training (LHTL)? What's the plan?
Atmospheric Pressure
Low Oxygen P_IO_2 ↓
Arterial hypoxemia S_aO_2 ↓
HIF-2α
Epo ↑
Kidney
Erythropoesis ↑
Hemoglobin mass ↑
Hemoglobin
Bone marrow
Erythrocytes
O_2 transport capacity of the blood ↑
Aerobic performance ↑ VO_{2max}
Levine & Stray-Gundersen, 2005
Federal Office of Sport FOSPO
Swiss Federal Institute of Sport Magglingen SFISM
38

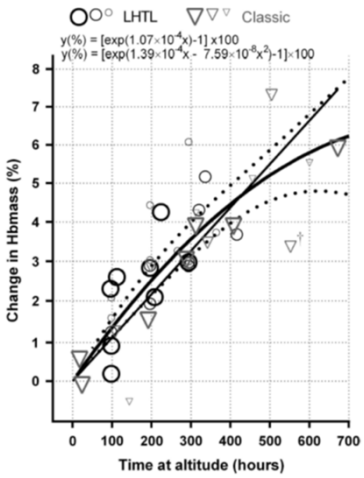
3) Does hemoglobin mass increase with altitude training (LHTL)?



Wilber 2007; Millet et al. 2010 & 2013

LH = live high; TH = train high; TL = train low; LL = live low; LHTLH = live high-train low and high; IHE = intermittent hypoxic exposure; CHT = continuous hypoxic training; IHT = intermittent hypoxic training; RSH = repeated sprint training in hypoxia; IHIT = intermittent hypoxic exposure during interval training.

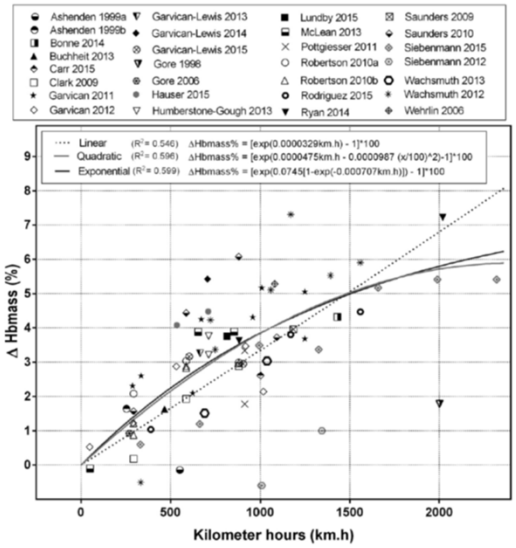
3) Does hemoglobin mass increase with altitude training (LHTL)? Hypoxic dose?



+ 1 – 1.5% / 100hours (>2200m)

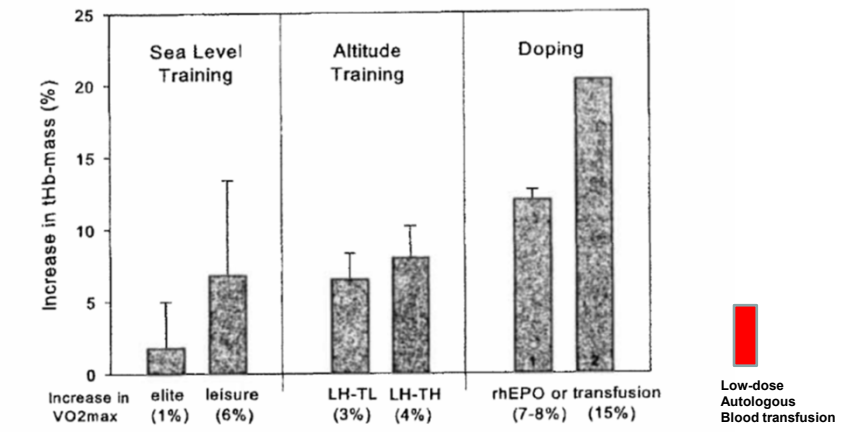
Gore et al., Br J Sports Med, 2013

3) Does hemoglobin mass increase with altitude training (LHTL)?



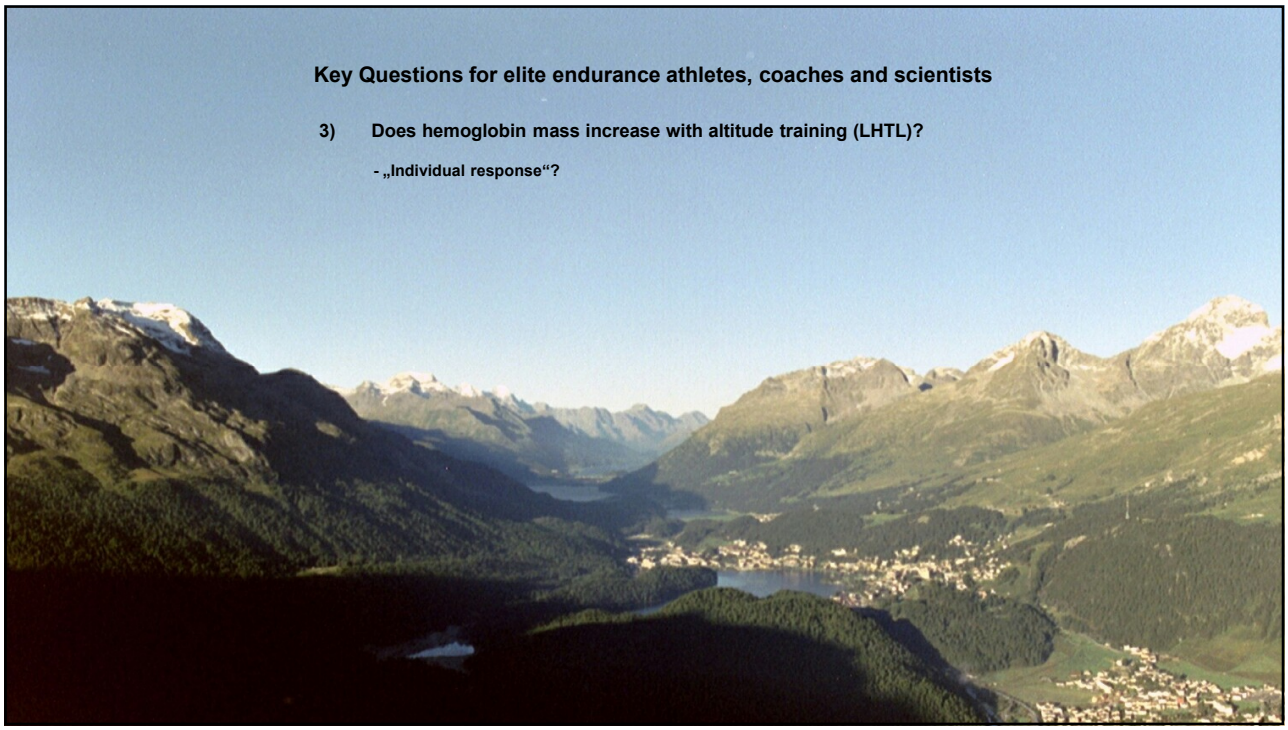
Garvican et al., J Applied Physiol, 2016

2 c) Increased hemoglobin mass with altitude training



Schmidt W & Prommer N. Exercise and Sport Sciences Reviews, 2010, 68-75

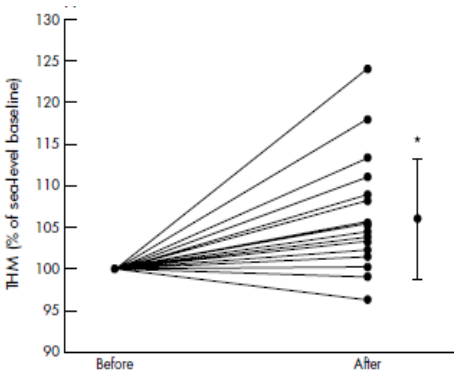
Bejder et al. Med Sci Sports Exerc, 2019



3) Does hemoglobin mass increase with altitude training (LHTL)?

Individual response?

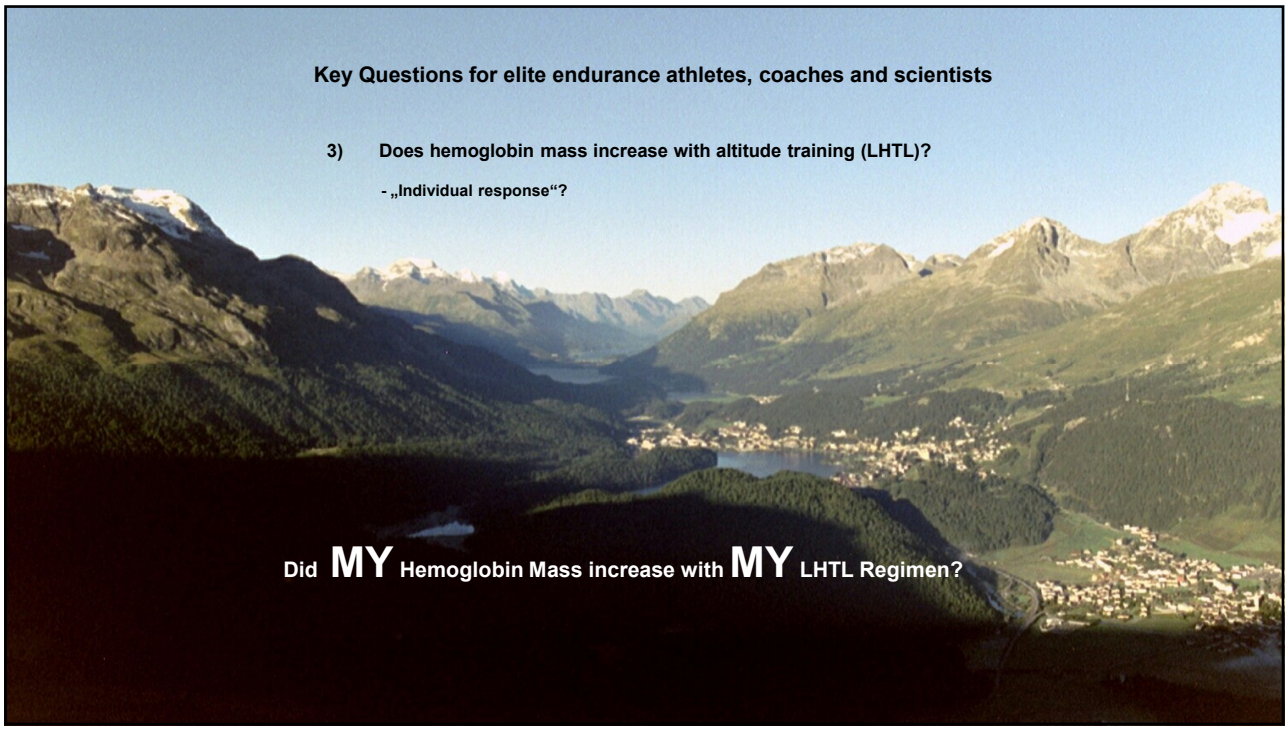
=> What is technical variation and what is a real physiological change?



Classic altitude training
- 3 weeks; 2100-2300 m
- 16 elite junior swimmers

What is the problem when I want to consult athletes individually?

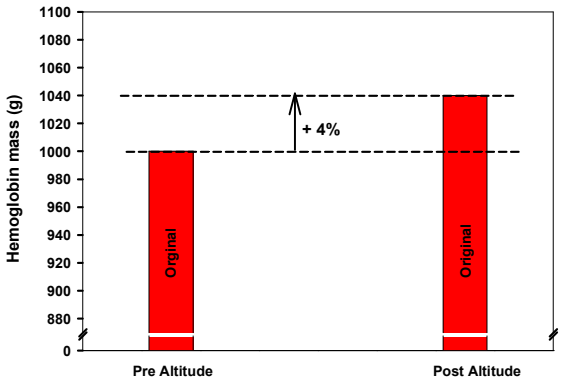
Friedmann et al. 2005



3) Does hemoglobin mass increase with altitude training (LHTL)?

Individual response?

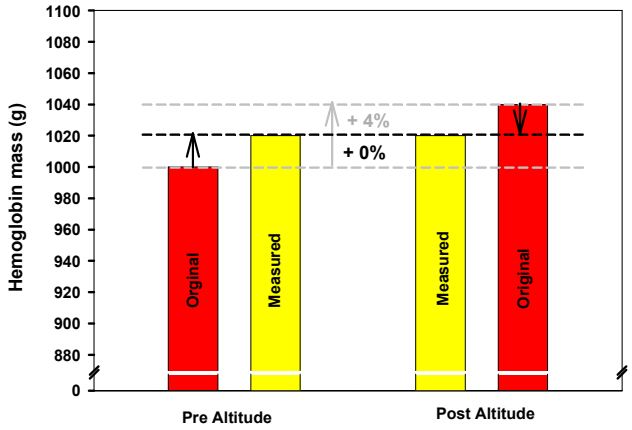
=> What is technical variation and what is a real physiological change?



3) Does hemoglobin mass increase with altitude training (LHTL)?

Individual response?

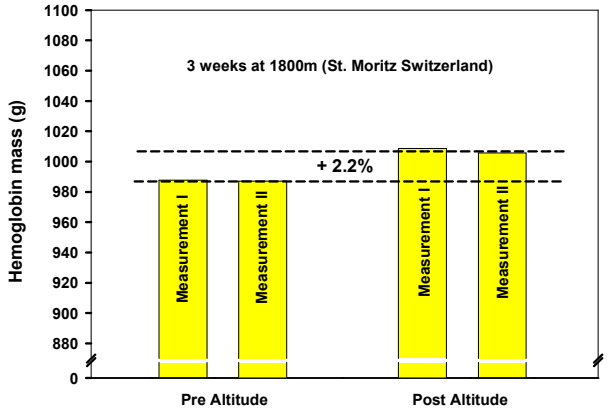
=> What is technical variation and what is a real physiological change?



3) Does hemoglobin mass increase with altitude training (LHTL)?

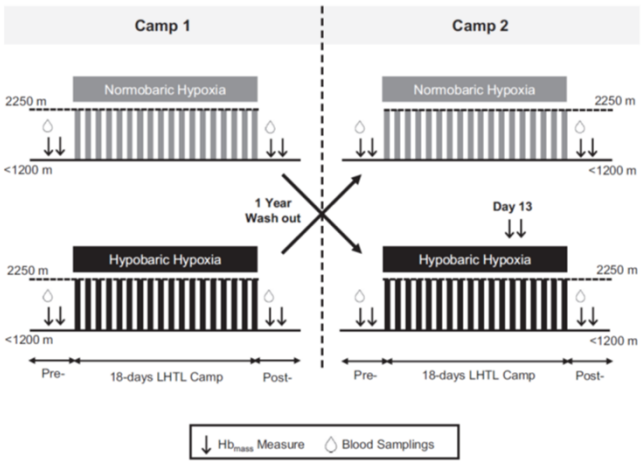
Individual response?

=> What is technical variation and what is a real physiological change?



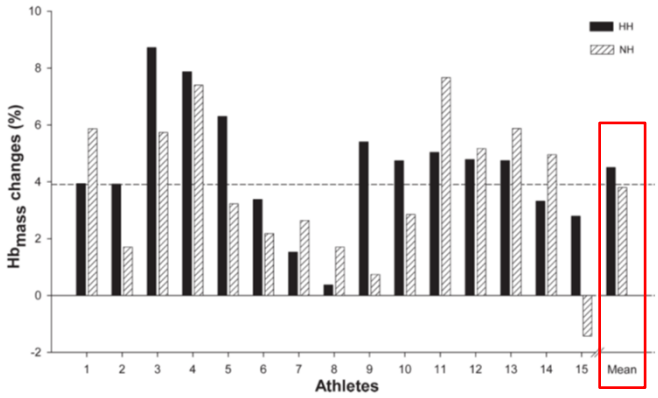
3) Does hemoglobin mass increase with altitude training (LHTL)?

=> can altitude tents be used?



3) **Does hemoglobin mass increase with altitude training (LHTL)?**

=> can altitude tents be used?



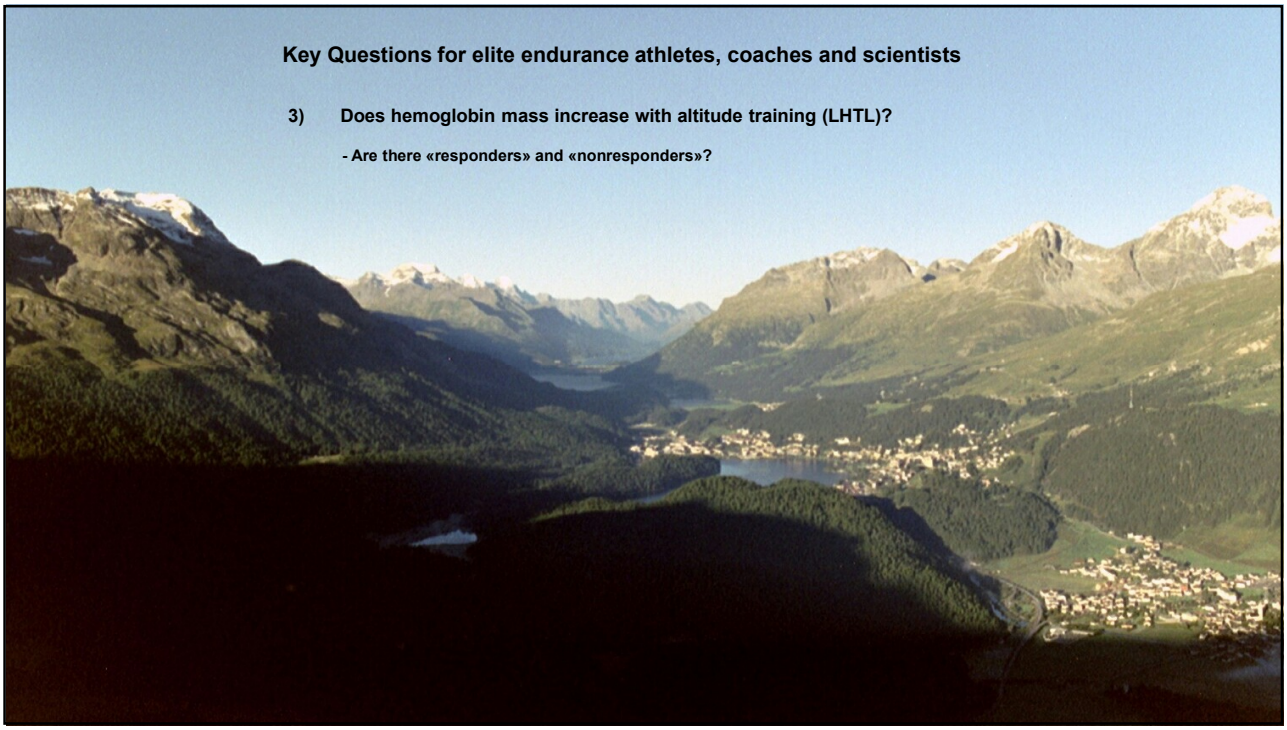
Variation between 0 to + 10%

Hauser A, Schmitt L, Troesch S, Saugy JJ, Cejulea RC, Faiss R, Robinson N, Millet GP and Wehrlin JP (JAP, 2017)

Key Questions for elite endurance athletes, coaches and scientists

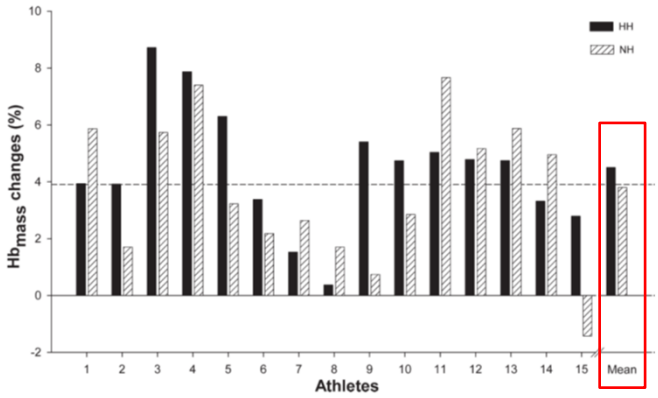
3) **Does hemoglobin mass increase with altitude training (LHTL)?**

- Are there «responders» and «nonresponders»?



3) Does hemoglobin mass increase with altitude training (LHTL)?

=> Are there «responders» or «nonresponders»?

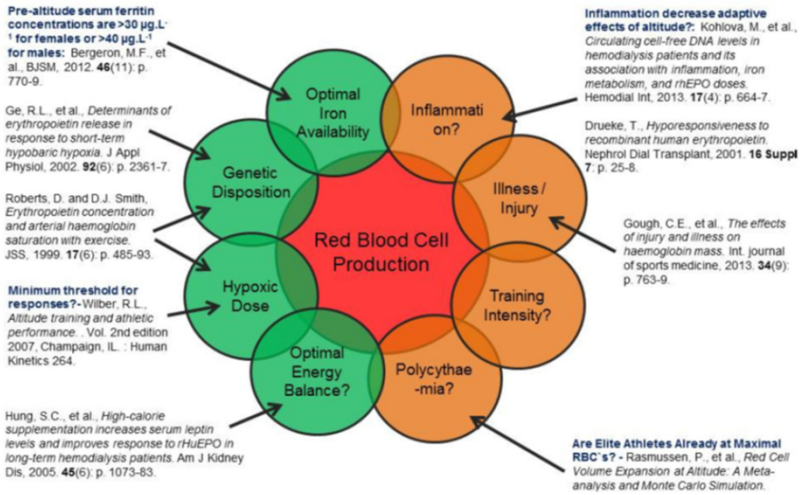


Variation between 0 to + 10%

Hauser A, Schmitt L, Troesch S, Saugy JJ, Cejulea RC, Faiss R, Robinson N, Millet GP and Wehrlin JP (JAP, 2017)

3) Does hemoglobin mass increase with altitude training (LHTL)?

Are there «responders» or «nonresponders»



Slide adapted from Garvican (USOC IATS 2013 Conference)

3) Does hemoglobin mass increase with altitude training (LHTL)?

Are there «responders» or «nonresponders»?

Example: Gold medalist endurances discipline Olympic Games (Switzerland):

2015: **Live high-train low altitude training camp 400hours at 2500m**

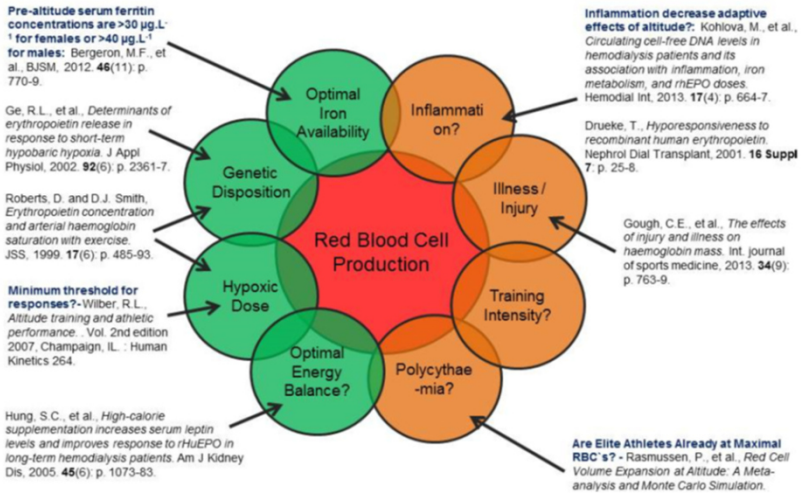
=> Hemoglobin mass +5%

2016: **Identical live high-train low altitude training camp 400hours at 2500m**

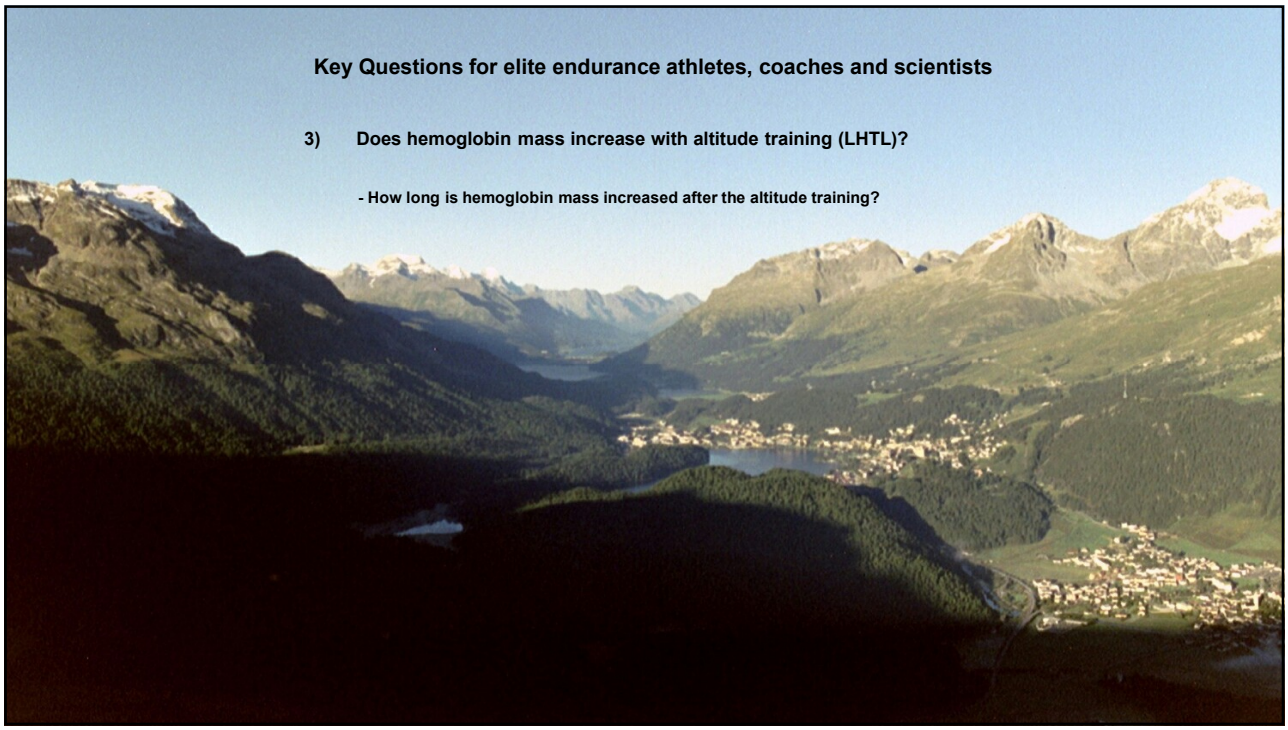
=> Hemoglobin mass +0.2%

3) Does hemoglobin mass increase with altitude training (LHTL)?

Individual response? (Can be different with each LHTL camp)



Slide adapted from Garvican (USOC IATS 2013 Conference)



Key Questions for elite endurance athletes, coaches and scientists

3) Does hemoglobin mass increase with altitude training (LHTL)?

- How long is hemoglobin mass increased after the altitude training?

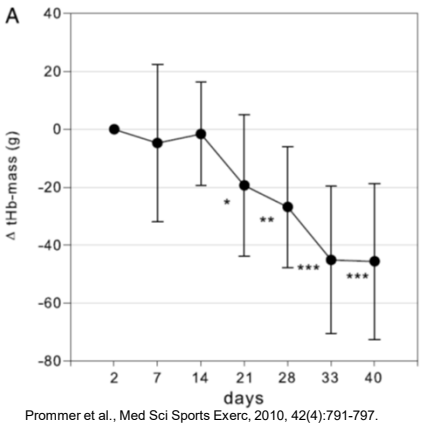
3) Does hemoglobin mass increase with altitude training?

=> How long is hemoglobin mass increased after altitude training?

Total Hemoglobin Mass and Blood Volume of Elite Kenyan Runners

NICOLE PROMMER[1], STEFANIE THOMA[2], LENNART QUECKE[1], THOMAS GUTEKUNST[1], CHRISTIAN VÖLZKE[3], NADINE WACHSMUTH[1], ANDREAS MICHAEL NIESS[2], and WALTER SCHMIDT[1]

[1]Department of Sports Medicine and Sports Physiology, University of Bayreuth, Bayreuth GERMANY; and [2]Department of Internal Medicine, Sports Medicine, University of Tübingen, Tübingen, GERMANY



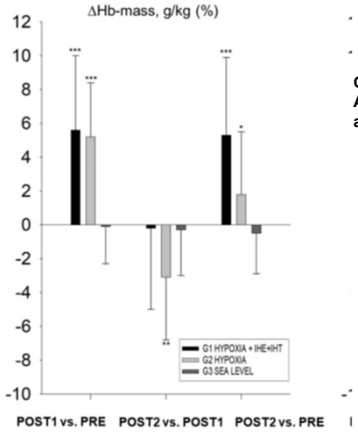
Prommer et al., Med Sci Sports Exerc, 2010, 42(4):791-797.

Living altitude Kenyan Runners:
Before 2090m, then travelled to 340m asl.

- 5.5% Hemoglobin mass after 33 days

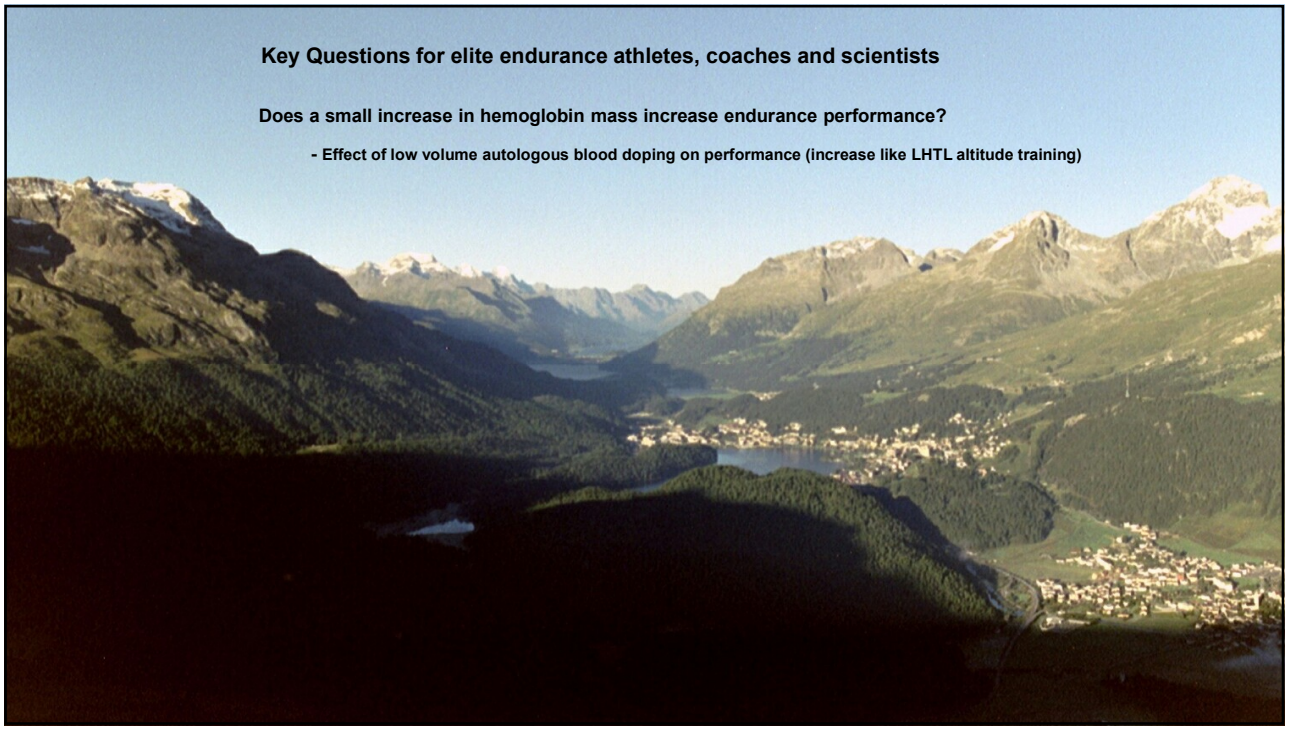
3) **Does hemoglobin mass increase with altitude training?**

=> How long is hemoglobin mass increased after altitude training?



Can elevated Hb_{mass} be maintained 1 month after the LHTL
Altitude training camp (2 h hypoxia at rest + 1 h hypoxic training every third day) after the altitude training camp?

Peltonen J, Leppävuori A, Lehtonen E, Mikkonen R, Kettunen O, Nummela A, Othonen O, Gagnon DD, Wehrlin JP, Wilber RL, Linnamo V. ACSM Kongress 2023, Denver, USA.



Does a small increase in hemoglobin mass increase performance (like with LHTL)?

=> Effect of a low-volume autologous blood transfusion?

Med Sci Sports Exerc. 2019 Apr;51(4):692-700. doi: 10.1249/MSS.0000000000001837.

Time Trial Performance Is Sensitive to Low-Volume Autologous Blood Transfusion.

Bejder J[1], Breenfeldt Andersen A[1], Solheim SA[1], Gybel-Brask M[2], Secher NH[3], Johansson PI[2], Nordsborg NB[1].

Author information

Abstract

PURPOSE: This study tested the hypothesis that **autologous blood transfusion** (ABT) of ~50% of the red **blood** cells (RBC) from a standard 450-mL phlebotomy would increase mean power in a cycling **time trial**. In addition, the study investigated whether further ABT of RBC obtained from another 450-mL phlebotomy would increase repeated cycling sprint ability.

METHODS: In a randomized, double-blind, placebo-controlled crossover design (3-month wash-out), nine highly trained male subjects donated two 450-mL **blood** bags each (BT **trial**) or were sham phlebotomized (PLA **trial**). Four weeks later, a 650-kcal **time trial** (n = 7) was performed 3 d before and 2 h after receiving either ~50% (135 mL) of the RBC or a sham **transfusion**. On the following day, **transfusion** of RBC (235 mL) from the second donation or sham **transfusion** was completed. A 4 × 30-s all-out cycling sprint interspersed by 4 min of recovery was performed 6 d before and 3 d after the second ABT (n = 9).

RESULTS: The mean power was increased in **time** trials from before to after **transfusion** ($P < 0.05$) in BT (213 ± 35 vs 223 ± 38 W; mean ± SD) but not in PLA (223 ± 42 vs 224 ± 46 W). In contrast, the mean power output across the four 30-s sprint bouts remained similar in BT (639 ± 35 vs 644 ± 26 W) and PLA (638 ± 43 vs 639 ± 25 W).

CONCLUSIONS: ABT of only ~135 mL of RBC is sufficient to increase mean power in a 650-kcal cycling **time trial** by ~5% in highly trained men. In contrast, a combined high-volume **transfusion** of ~135 and ~235 mL of RBC does not alter 4 × 30-s all-out cycling **performance** interspersed with 4 min of recovery.

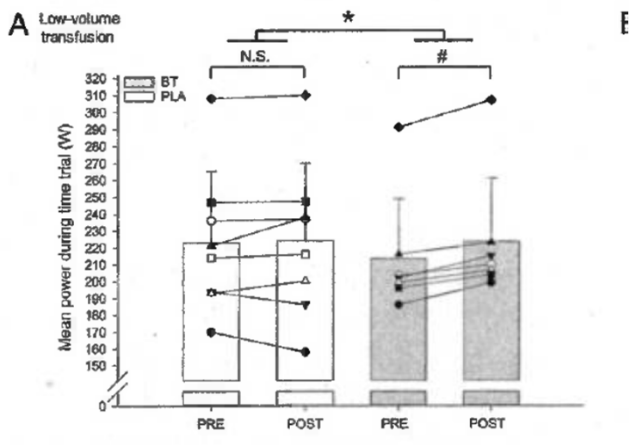
135ml RBC = 300ml Blood (Hct 45%)

Hct 45% = Hb 15g/dl

3dl Blood * 15g/dl = 45g Hemoglobin

Does a small increase in hemoglobin mass increase performance?

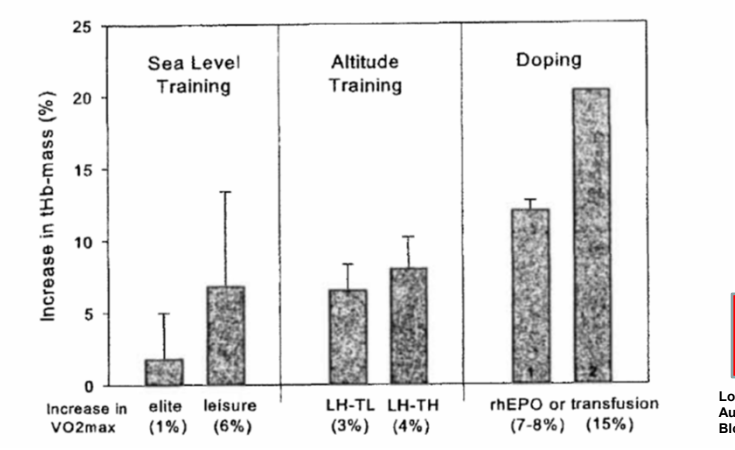
=> Effect of a low-volume autologous blood transfusion?



Bejder et al., Med Sci Sports Exerc, 2019, 51(4):692-700.

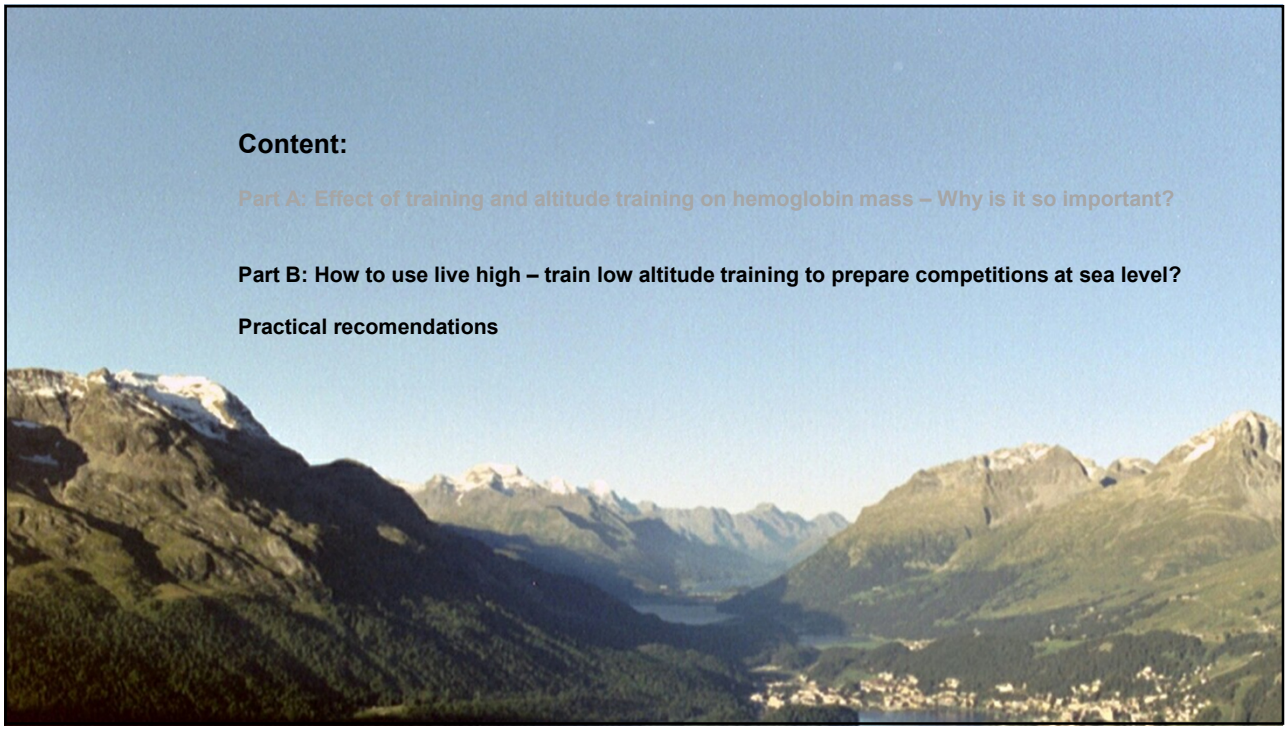
Does a small increase in hemoglobin mass increase performance?

=> Effect of a low-volume autologous blood transfusion?



Bejder et al. MSSE 2019

Schmidt W & Prommer N. Exercise and Sport Sciences Reviews, 2010, 68-75



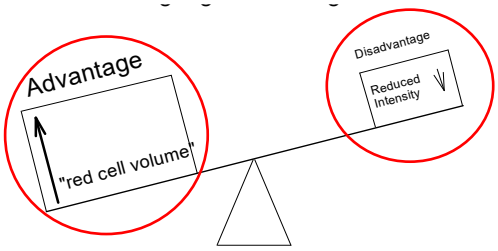
Content:

Part A: Effect of training and altitude training on hemoglobin mass – Why is it so important?

Part B: How to use live high – train low altitude training to prepare competitions at sea level?

Practical recomendations

Part B: How do we support endurance athletes in Switzerland?



"Living high-training low": effect of moderate-altitude acclimatization with low-altitude training on performance

BENJAMIN D. LEVINE[1] AND JAMES STRAY-GUNDERSEN[2]
[1]Institute for Exercise and Environmental Medicine, Presbyterian Hospital of Dallas 75231; and
[2]Baylor/The University of Texas Southwestern Sports Science Research Center,
The University of Texas Southwestern Medical Center, Dallas, Texas 75235

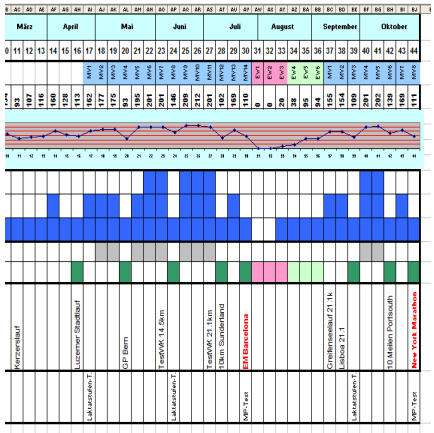
Levine & Stray-Gundersen, J Appl Physiol, 1997

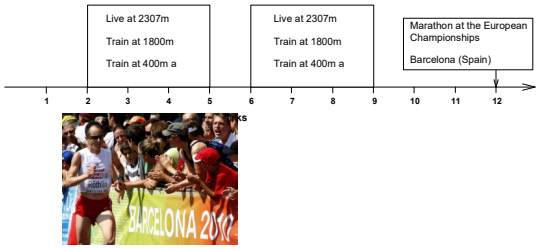
Part B: How do we support endurance athletes in Switzerland?

=> How we support endurance athletes and coaches – Important aspects

a) Build a team: Athlete, Coach, Physician, Nutrician, Scientist!

b1) Plan altitude training camp perfectly (timing in season, hypoxic dose, training, Nutrition, Recovery, Supplemtents (iron, vitamin b12, folic acid etc.) on individual base





Part B: How do we support athletes in Switzerland

=> Important aspects

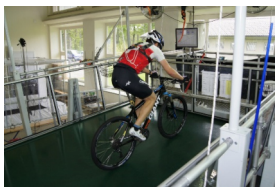
b2) Long term planning!

2010 Altitude Training „Best Practice“

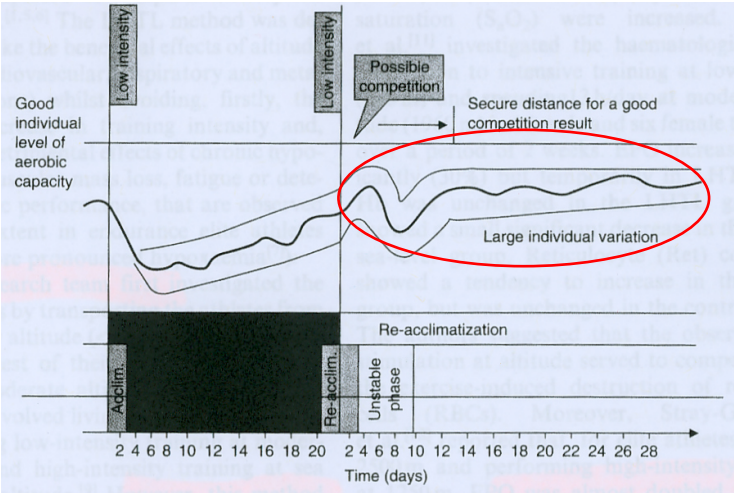
2011 Individual Adaptations

2012 Olympic Games London

Part B: => How we support endurance athletes and coaches – Important aspects



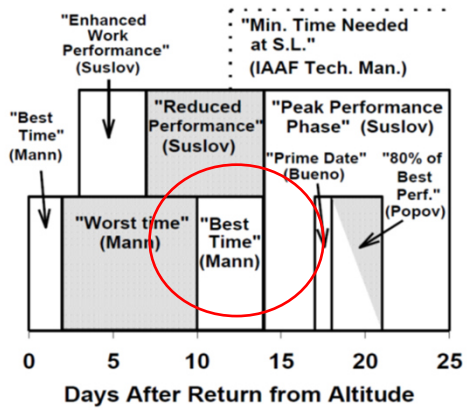
Part B: => How we support endurance athletes and coaches – Important aspects



Timing of competition!

Millet et al., Sports Med, 2010 (modified after Reiss)

Part B: => How we support endurance athletes and coaches – Important aspects



Chapman RF, 2011

Part B: => How we support endurance athletes and coaches – Important aspects

Planning of training load and training intensity!

Hypoxic training model: to prepare a period of competitions at sea level

Hypoxia		■	■	■					
Normoxia					■	■	■	■	■
Training load	Very high			■					■
	High			■			■		■
	Medium		■	■		■	■		■
	Low	■	■	■		■	■		■
	Very low	■	■	■	■	■	■	■	■
Training intensity		Int ≤ VT_1 strength training	Int ≤ VT_1 Int ≤ VT_2 strength training	Int ≤ VT_1 Int ≤ VT_2 Int ≤ MAP strength training	Int ≤ VT_1	Int ≤ VT_1 Int ≤ VT_2 strength training	Int ≤ VT_1 Int ≤ VT_2 Int ≤ MAP strength training	Short recovery Int ≤ VT_1	Competition period at sea level
Days		7	7	7	7	6	5	2 to 3	1 to 15

Millet et al., Sports Med, 2010

21 days after LHTL

Timing of altitude training camp

Draft: FIS CROSS-COUNTRY WORLD CUP 2021/22

Date	Day	Site	Nation	Women	Men	Remarks
Period I						
Ruka Triple						
26.11.	Fri	Ruka	FIN			
27.11.	Sat	Ruka	FIN			
28.11.	Sun	Ruka	FIN			
04.12.	Sat	Lillehammer	NOR			
05.12.	Sun	Lillehammer	NOR			
11.12.	Sat	Davos	SUI			
12.12.	Sun	Davos	SUI			
18.12.	Sat	Dresden	GER			
19.12.	Sun	Dresden	GER			
Period II						
Tour de Ski						
01.01.	Sat	Lenzerheide	SUI			
02.01.	Sun	Lenzerheide	SUI			
04.01.	Tue	Oberstdorf	GER			
05.01.	Wed	Oberstdorf	GER			
07.01.	Fri	tbc	ITA			
08.01.	Sat	Val di Fiemme	ITA			
09.01.	Sun	Val di Fiemme	ITA			
Period III						
15.01.	Sat	tbc	tbc			
16.01.	Sun	tbc	tbc			
22.01.	Sat	Planica	SLO			
23.01.	Sun	Planica	SLO			
04.02. – 20.02.		OWG Beijing	CHN			
Period IV						
26.02.	Sat	Lahti	FIN			
27.02.	Sun	Lahti	FIN			
02.03.	Wed	Drammen	NOR			
05.03.	Sat	Oslo	NOR			
06.03.	Sun	Oslo	NOR			
12.03.	Sat	Falun	SWE			
13.03.	Sun	Falun	SWE			
World Cup Final						
18.03.	Fri	tbc	tbc			RUS / USA
19.03.	Sat	tbc	tbc			
20.03.	Sun	tbc	tbc			

FIS Nordic Junior World Ski Championships, tbc
Olympic Winter Games, Beijing (CHN), 04. – 20.02.2022

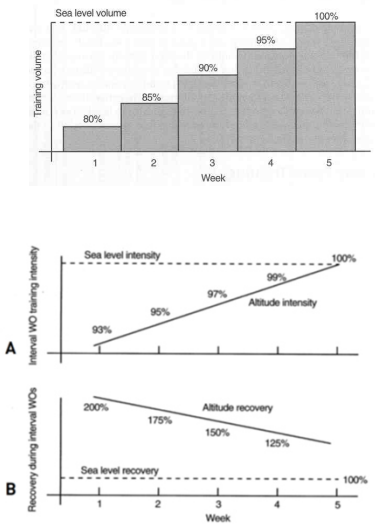
Difficult to prepare competitions with LHTL during the season –

You can not plan to compete at all competitions if you want prepare the Olympics in Beijing 2022 with LHTL

z.B. 3. - 23. January Altitude Training (12 days before OG)

=> Goal: 16-20 days before first competition

Part B: => How we support endurance athletes and coaches – Important aspects



=> Adapt training and recovery!

- Reduce training volume
- Increase recovery between training sessions
- Increase recovery time between intervalls
- Recovery is very important

  => Plan recovery!
- Listen to your body

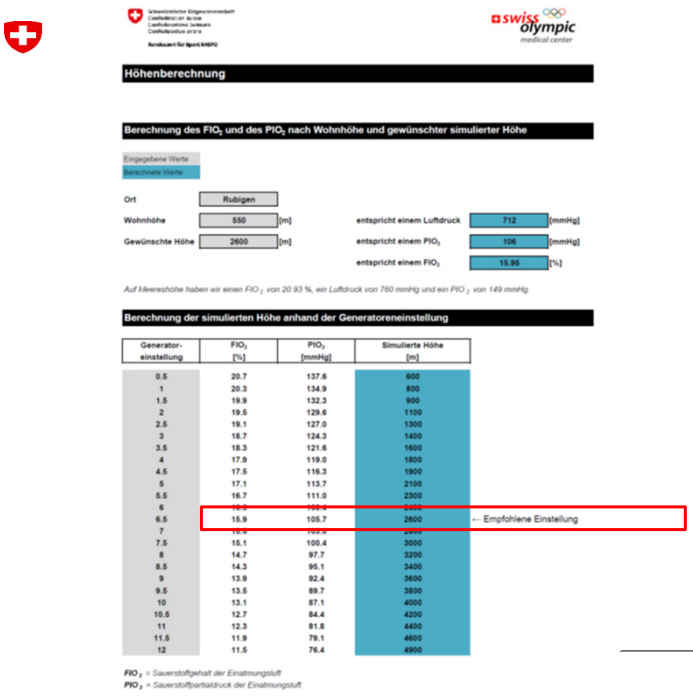
=> Danger of overreaching/overtraining!

Wilber, R. Altitude Training and Athletic Performance. Human Kinetics. 2004.

Part B: => How we support endurance athletes and coaches – Important aspects

c) Installation of altitude room at athlete's home (very easy with generators) or altitude tents?

=> Long periods at real altitude can be shortened with stays at home



Höhenberechnung

Berechnung des FIO_2 und des PIO_2 nach Wohnhöhe und gewünschter simulierter Höhe

Eingegebene Werte
Berechnete Werte

Ort	Rubigen			
Wohnhöhe	550	[m]	entspricht einem Luftdruck	712 [mmHg]
Gewünschte Höhe	2600	[m]	entspricht einem PIO_2	106 [mmHg]
			entspricht einem FIO_2	15.95 [%]

Auf Meereshöhe haben wir einen FIO_2 von 20.93 %, ein Luftdruck von 760 mmHg und ein PIO_2 von 149 mmHg

Berechnung der simulierten Höhe anhand der Generatoreneinstellung

Generator-einstellung	FIO_2 [%]	PIO_2 [mmHg]	Simulierte Höhe [m]	
0.5	20.7	137.6	600	
1	20.3	134.9	800	
1.5	19.9	132.3	900	
2	19.5	129.6	1100	
2.5	19.1	127.0	1300	
3	18.7	124.3	1400	
3.5	18.3	121.6	1600	
4	17.9	119.0	1800	
4.5	17.5	116.3	1900	
5	17.1	113.7	2100	
5.5	16.7	111.0	2300	
6	16.3	108.3	2500	
6.5	15.9	105.7	2600	← Empfohlene Einstellung
7	15.5	103.0	2800	
7.5	15.1	100.4	3000	
8	14.7	97.7	3200	
8.5	14.3	95.1	3400	
9	13.9	92.4	3600	
9.5	13.5	89.7	3800	
10	13.1	87.1	4000	
10.5	12.7	84.4	4200	
11	12.3	81.8	4400	
11.5	11.9	79.1	4600	
12	11.5	76.4	4900	

FIO_2 = Sauerstoffgehalt der Einatmungsluft
PIO_2 = Sauerstoffpartialdruck der Einatmungsluft

Part B: => How we support endurance athletes and coaches – Important aspects

Individualize altitude

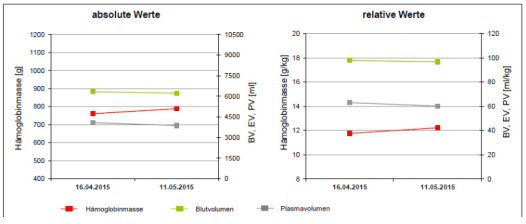
Part B: How to use live high-train low altitude training to prepare competitions at sea level

=> How we support endurance athletes and coaches – Important aspects

Informationen Höhentraining

Ort	Schnalstal	Höhe [m]	2030
Höhentage [d]	18	Höhenstunden [h]	281
Bemerkungen	LHTL		

Blutdaten (Mittelwerte aus Doppelmessung)	Vor Höhentraining	Nach Höhentraining	Veränderung (%)
absolute Hämoglobinmasse [g]	761	788	+ 3.5 %
relative Hämoglobinmasse [g/kg]	11.8	12.2	+ 4 %
absolutes Blutvolumen [ml]	6336	6229	- 1.7 %
relatives Blutvolumen [ml/kg]	97.9	96.7	- 1.2 %
absolutes Plasmavolumen [ml]	4082	3877	- 5 %
relatives Plasmavolumen [ml/kg]	63.1	60.2	- 4.6 %



d) Plan double measurement of hemoglobin mass

Part B: => How we support endurance athletes and coaches – Important aspects

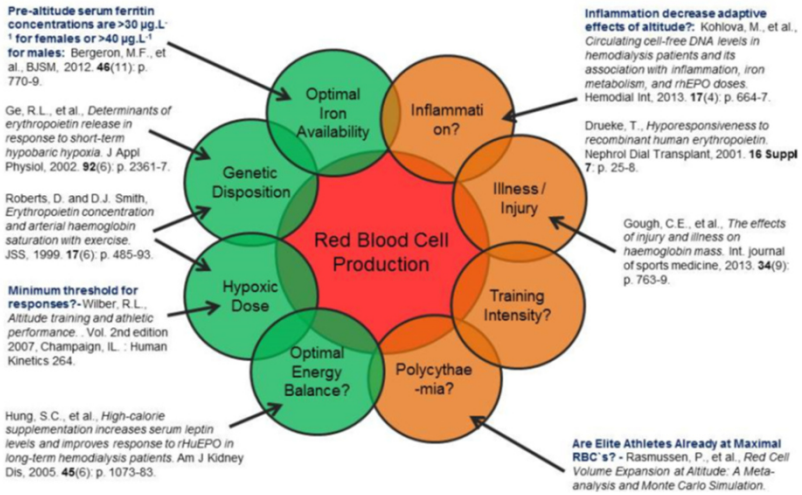
e) Control everything during the altitude training period

- **Training and training quality**
- **Hours at altitude (hypoxic dose)**
- **Sleep and sleep quality**
- **Profile of Mood State**
- **Body weight**
- **Rest heart rate**
- **Oxygen saturation during sleep**
- **Overall state of the athlete ++, +, +/-, -, --**
- **Competition after the LHTL camp (14 – 24 days after)**
- **etc.**

f) Evalutate the altitude training camp in the team (4 weeks after)

- **How was it?**
- **What did work, what did not work, why?**
- **What could we improve/change (hypoxic dose etc.)**
- **Does the athlete coach want to do it again**

Part B: => How we support endurance athletes and coaches – Important aspects



Slide adapted from Garvican (USOC IATS 2013 Conference)

Does live high-train low (LHTL) altitude training increase endurance performance?

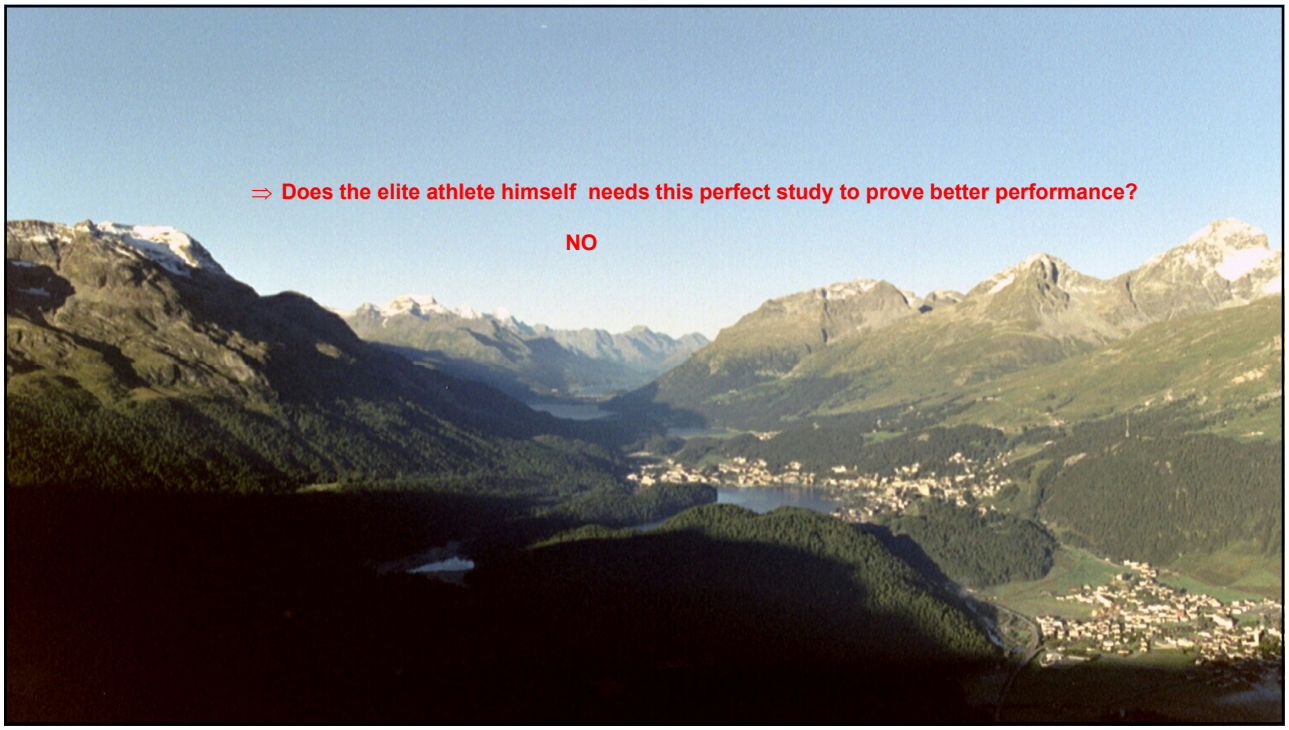
=> Results of studies with elite athletes?

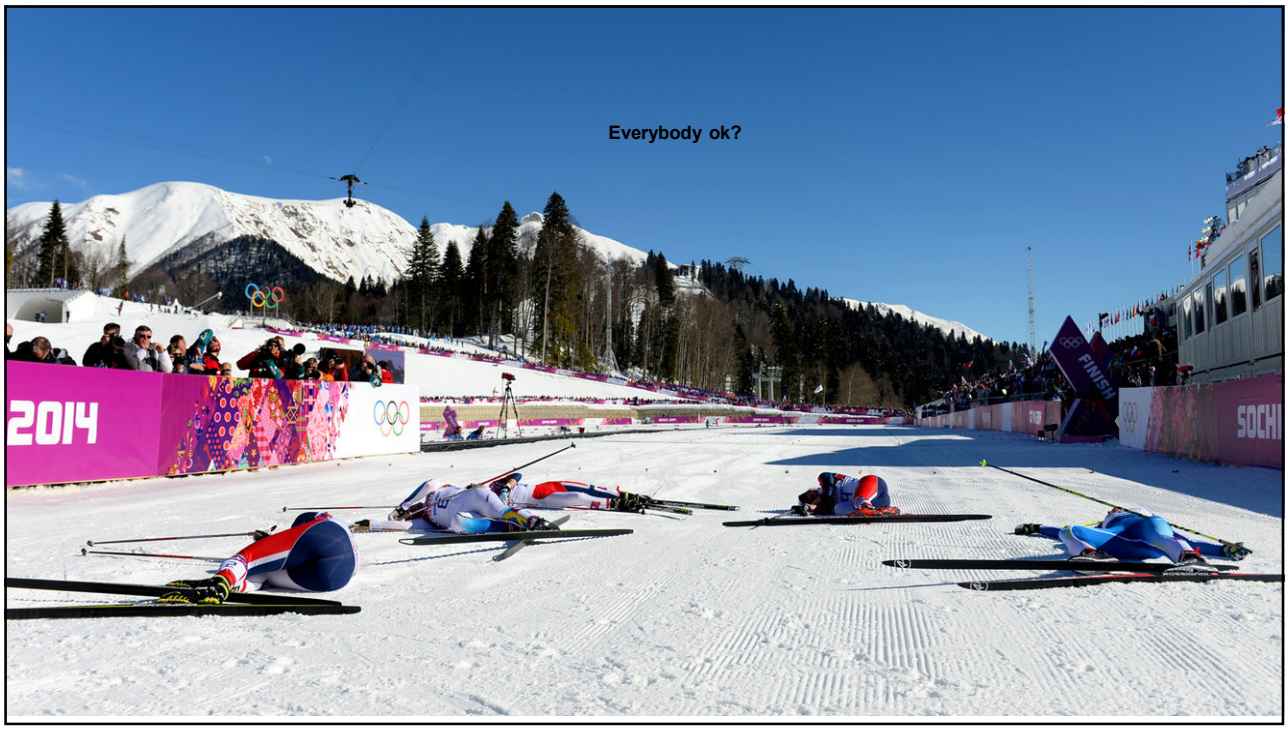
=> Impossible to prove – but not so important for elite sport athletes.

Subjects:
- World class elite endurance athletes (high n)
- Willing to perform best at pre- and posttest of a study and not at a competition
- «Responder» for hemoglobin mass increases with altitude training (genetic predisposition)

=> Succesful increase in hemoglobin mass with LHTL (double measurements)

Study design / Method:
- Athletes are their own controls (individual responses)
- Cross over design over one year (same training period) (BUT Athletes will be one year older!)
- YES, Blinded for the treatment (LHTL or sea level) => Placebo Effect
- NOT Blinded for the treatment => Training has to be adjusted to altitude or sea level conditions
- High enough hypoxic dose (Individually different)?
- Optimal preparation for the pre- and posttests (Peaking and Tapering)
  => Time of best performance should be at the posttests (not at races of the athletes)
- Optimal timing of the pre- and posttests («best time man»)
- Optimal iron availability
- Optimal energy balance
- No negative effects (inflamation, ilness, injury, overreaching, overtraining) during both periods
- Very precise and valide tests (hemoglobin mass) and performance
- etc.




Everybody ok?
2014
FINISH
SOCHI


Questions?