Preparation for Altitude
A Medical Perspective

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CONTENTS

- BEFORE: Preparation for altitude
- DURING: Maintenance at altitude
- AFTER: Expected results
- Field example
- Take home messages
- Questions

FAILURE OF RED CELL VOLUME TO INCREASE TO ALTITUDE EXPOSURE IN IRON DEFICIENT RUNNERS

J. Stray-Gundersen, C. Alexander*, A. Hochstein, D. deLemos*, BD Levine; Baylor/UT Southwestern Sports Science Center, Dallas, TX 75246

		Ferritin§		Hct		Red Cell Volume§		Diet Iron	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
Norm	F	69±10	32±6*	43±1	44±1	27.3±1.0	29.8±0.8*	25±3	26±4
Low	F	15±3†	14±3	40±1	41±1	27.0±1.0	27.4±1.3	23±5	38±9

§p<0.10 ANOVA, *p<0.01 pre/post, †p<0.01 norm F/low F

IRON STATUS

- **Screening: ferritin.**
- Adequate iron stores are essential prior to arrival at altitude.
- Check iron status 8-10 weeks prior to ensure adequate time to replenish stores, if necessary.*
- Deficiency: ferritin <30 (minimum value)
- Replete: ferritin >60 (♀: >70)
- Sea level: ≥30 mg/day. Consider increasing at altitude if stores <60 prior.

*Koehle MS, Cheng I, Sporer B. Canadian Academy of Sport and Exercise Medicine position statement: athletes at high altitude. Clin J Sport Med. 2014 Mar;24(2):120-7. doi: 10.1097/JSM.0000000000000024. PMID: 24569430.

The Effects of Injury and Illness on Haemoglobin Mass

C. E. Gough[1,2], K. Sharpe[3], L. A. Garvican[1], J. M. Anson[4], P. U. Saunders[1,2], C. J. Gore[1,2,5]

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[2] Faculty of Health, University of Canberra, Canberra, Australia
[3] Department of Mathematics and Statistics, University of Melbourne, Melbourne, Australia
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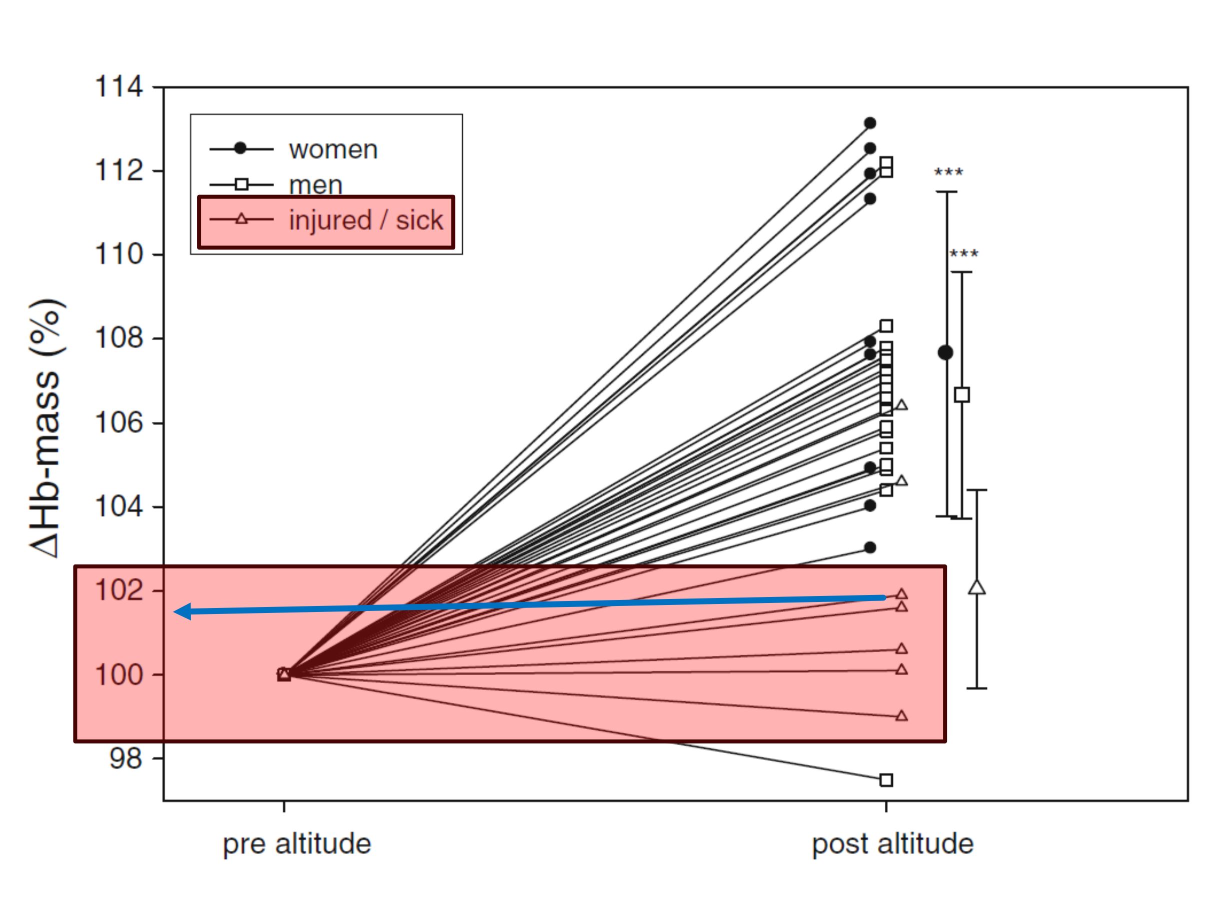
[5] Exercise Physiology Laboratory, School of Education, Flinders University, Adelaide, Australia

Factor/Variable	Effect on $\ln(Hb_{mass})$	95 % Confidence Interval ($\ln(Hb_{mass})$)	Effect on Hb_{mass} (%)	95 % Confidence Interval (%)	p-value
reduced training †	−0.023	−0.044 to −0.003	−2.3	−4.3 to −0.3	0.027
surgery	−0.027	−0.054 to −0.001	−2.7	−5.4 to −0.1	0.045
ln(body mass) #	0.138	−0.210 to 0.485	14.7	−18.9 to 62.4	0.435
altitude	0.024	0.003 to 0.045	2.4	0.3 to 4.6	0.025
iron supplementation	0.041	0.016 to 0.065	4.2	1.6 to 6.7	0.002

5%

The effects of classic altitude training on hemoglobin mass in swimmers

N. B. Wachsmuth · C. Völzke · N. Prommer ·
A. Schmidt-Trucksäss · F. Frese · O. Spahl ·
A. Eastwood · J. Stray-Gundersen · W. Schmidt



"…no increase was found in ill and injured athletes…"

"…the altitude effect on Hb-mass… decisively depends on the health status [of the athlete]"

INFLAMMATION

- **Screening: CRP, ESR, WCC/diff.**
- Pro-inflammatory state inhibits formation of red blood cells.
- Ensure no active inflammatory processes (injury, illness etc.) present prior to arrival at altitude.
- Additional considerations:
  - Sun protection*

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PREPARING FOR ALTITUDE

- Bloods*:
  - BASELINE: Hb, HCT, RCCs +- EPO/retics%*
  - IRON: ferritin,
  - INFLAMMATION: CRP, ESR

  (Duplicate analysis + same lab, if possible.)
- Clinical screening:
  - Injury/Illness status
- Planning:
  - ≥2 000 m + ≥21 days + ≥12 h p/day ≈ 300 h**
  - Hb mass - CO rebreathing method (x2 <24h apart → mean).

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MAINTENANCE AT ALTITUDE

- Medical team:
  - Injury/Illness status
  - Quality of sleep
  - Vital: AM pulse + SpO_2 + weight + temperature
  - Hydration status – urine SG / salivary osmolarity
  - Hb mass readings

*Brocherie, F., Schmitt, L. & Millet, G.P. Hypoxic dose, intensity distribution, and fatigue monitoring are paramount for "live high-train low" effectiveness. *Eur J Appl Physiol* **117**, 2119–2120 (2017). https://doi.org/10.1007/s00421-017-3664-3

DATE	RIDER	LOCATION	MORNING PULSE (BPM)	SpO2	WEIGHT (kg.)	SALIVA (mOsm)	TEMPERATURE (°C)	ALTITUDE (m)

SLEEP QUALITY	
1	Horrible
2	Poor
3	Bad
4	Average
5	Good
6	Better
7	Best

MAINTENANCE AT ALTITUDE

- Medical team:
  - Injury/Illness status*
  - Quality of sleep
  - Vital: AM pulse + SpO_2 + weight + temperature
  - Hydration status – urine SG / salivary osmolarity
  - Hb mass readings
- Performance team:
  - Training load*
  - Hypoxic dose* (hours - NH vs HH)
  - Fatigue monitoring*

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Anticipated results

Minimum exposure: ≥2 000 m ; ≥21 days ; ≥12 h p/day → ≈300 hypoxic hours.

↓

1,1% ↑ in Hb mass per 100 hours*

*CE, Robertson EY, Wachsmuth NB, Clark SA, McLean BD, Friedmann-Bette B, Neya M, Pottgiesser T, Schumacher YO, Schmidt WF. *Altitude training and haemoglobin mass from the optimised carbon monoxide rebreathing method determined by a meta-analysis.* Br J Sports Med 47, Suppl 1: i31–i39, 2013. doi:10.1136/bjsports-2013-092840.

1,1% ↑ in Hb
mass per 100 hours*

BUT…

Similar Hemoglobin Mass Response in Hypobaric and Normobaric Hypoxia in Athletes

ANNA HAUSER[1,2], LAURENT SCHMITT[2,3], SEVERIN TROESCH[1], JONAS J. SAUGY[2], ROBERTO CEJUELA-ANTA[4], RAPHAEL FAISS[1], NEIL ROBINSON[5], JON P. WEHRLIN[1], and GRÉGOIRE P. MILLET[2]

x2 camps; both 18 days:
HH = 4,4% (310 hours) = 1,4%/100h
NH = 4,1% (225 hours) = 1,8%/100h

Individual hemoglobin mass response to normobaric and hypobaric "live high–train low": A one-year crossover study

Anna Hauser,[1,2] Severin Troesch,[1] Jonas J. Saugy,[2] Laurent Schmitt,[3] Roberto Cejuela-Anta,[4] Raphael Faiss,[2] Thomas Steiner,[1] Neil Robinson,[5] Grégoire P. Millet,[2]* and Jon P. Wehrlin[1]*

x2 camps; both 18 days:
HH = 4,5% (310 hours) = 1,5%/100h
NH = 3,8% (225 hours) = 1,7%/100h

≥2 000 m ; ≥21 days ; ≥12 h p/day

≈300 hypoxic hours

BUT…

Time course of the hemoglobin mass response to natural altitude training in elite endurance cyclists

L. Garvican[1,2], D. Martin[1], M. Quod[1], B. Stephens[1], A. Sassi[3], C. Gore[1,2]

Responses at lower hypoxic dose.
HH (2 760 m):
11 days **(+-220 hours)**: 2.9%.

The effects of classic altitude training on hemoglobin mass in swimmers

N. B. Wachsmuth · C. Völzke · N. Prommer · A. Schmidt-Trucksäss · F. Frese · O. Spahl · A. Eastwood · J. Stray-Gundersen · W. Schmidt

"…no increase was found in ill and injured athletes…"

"…the altitude effect on Hb-mass… decisively depends on the health status [of the athlete]"

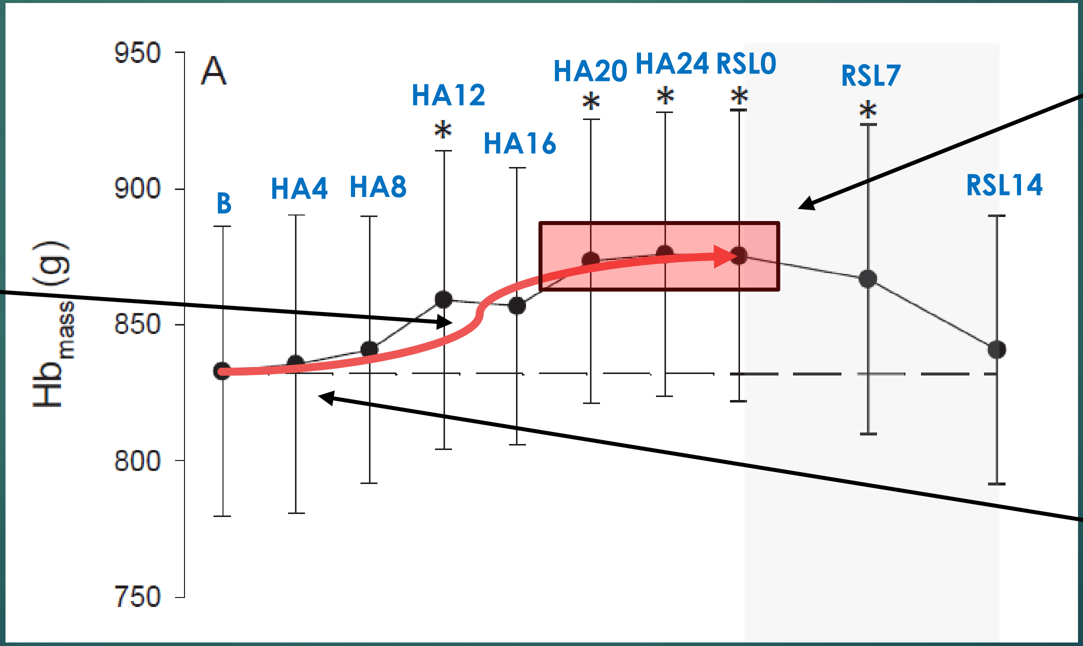
Large study ♀ + ♂ over 2 years.
Normal variance: ♂ = 3,0% / ♀ = 2,7%
1 360 m: 3,8%
(2 320 m: 7,2%)

Hemoglobin mass and intravascular volume kinetics during and after exposure to 3,454 m altitude

Siebenmann C[1,2], Cathomen A[3], Hug M[1], Keiser S[1], Lundby AK[1], Hilty MP[4], Goetze JP[5], Rasmussen P[6] and Lundby C[1,7]

9 pax
Hb mass every 4d
28 days at HH (3 435 m) = 675 hours (LHTH)
ΔHb mass = 0,4-1,6%/100h

BUT…



Marked increase in the probability for Hb mass to reach a plateau after 20 – 24 days

Highest rate of Hb mass increase occurred after 14.9 ± 5.2 days
=
4.04 ± 1.02 g/d
(>>overall rate)

Varied onset of increase. ≥4d
(latest = 12d)

Avg. rate =1.82 ± 0.81 g/d

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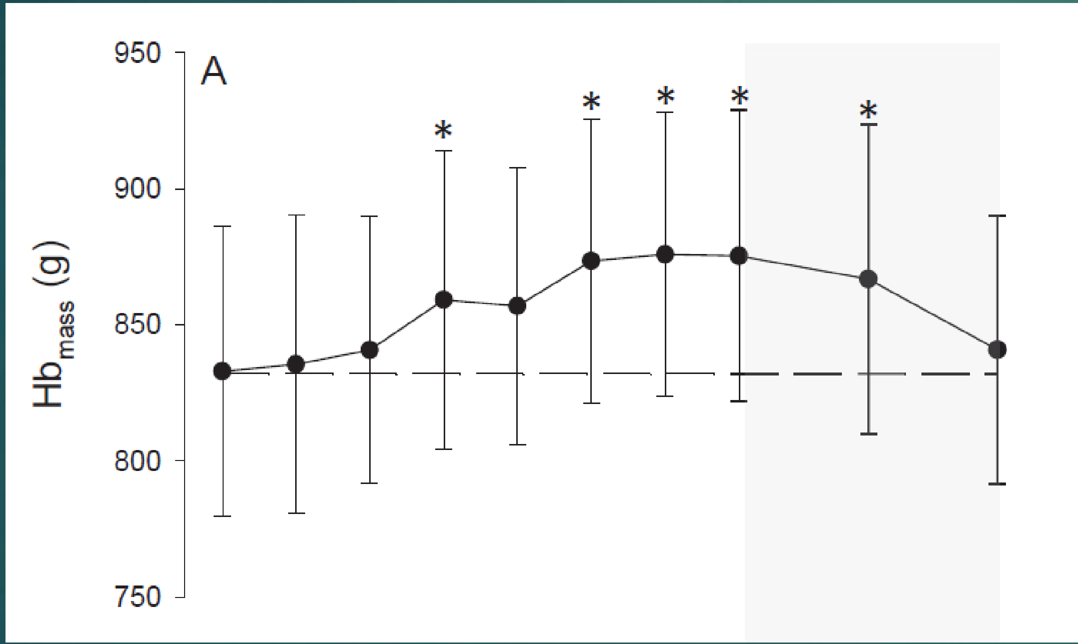

TAKE HOME MESSAGES:

- Increases in a sigmoidal pattern.
- Limited capacity to increase: reaches a plateau.
- Maximal rate > overall rate.
- Increases occur as early as 100 h (4d)

Anticipated results

Minimum exposure: ≥2 000 m ; ≥21 days ; ≥12 h p/day → ≈300 hypoxic hours.

↓

1,1% ↑ in Hb mass per 100 hours*

(large interindividual variation)

*CE, Robertson EY, Wachsmuth NB, Clark SA, McLean BD, Friedmann-Bette B, Neya M, Pottgiesser T, Schumacher YO, Schmidt WF. *Altitude training and haemoglobin mass from the optimised carbon monoxide rebreathing method determined by a meta-analysis.* Br J Sports Med 47, Suppl 1: i31–i39, 2013. doi:10.1136/bjsports-2013-092840.

Anticipated results

Minimum exposure: ≥2 000 m ; ≥21 days ; ≥12 h p/day → ≈300 hypoxic hours.

1,1% ↑ in Hb mass per 100 hours*

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1 g ↑ in Hb mass = 4 ml/min/kg ↑ in VO2max**

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**Schmidt W, Prommer N. Impact of alterations in total hemoglobin mass on VO 2max. Exerc Sport Sci Rev 38: 68–75, 2010. doi:10.1097/JES.0b013e3181d4957a.

Anticipated results

1 g ↑ in Hb mass = 4 ml/min/kg ↑ in VO2max**

(large interindividual variation)

- EPO response to hypoxia
- Genetic predisposition
- 'Hypoxic tolerance'
- Different baseline conditions (e.g. low pre-altitude ferritin)

IMPORTANCE OF INDIVIDUAL HB MASS MONITORING

*CE, Robertson EY, Wachsmuth NB, Clark SA, McLean BD, Friedmann-Bette B, Neya M, Pottgiesser T, Schumacher YO, Schmidt WF. *Altitude training and haemoglobin mass from the optimised carbon monoxide rebreathing method determined by a meta-analysis.* Br J Sports Med 47, Suppl 1: i31–i39, 2013. doi:10.1136/bjsports-2013-092840.
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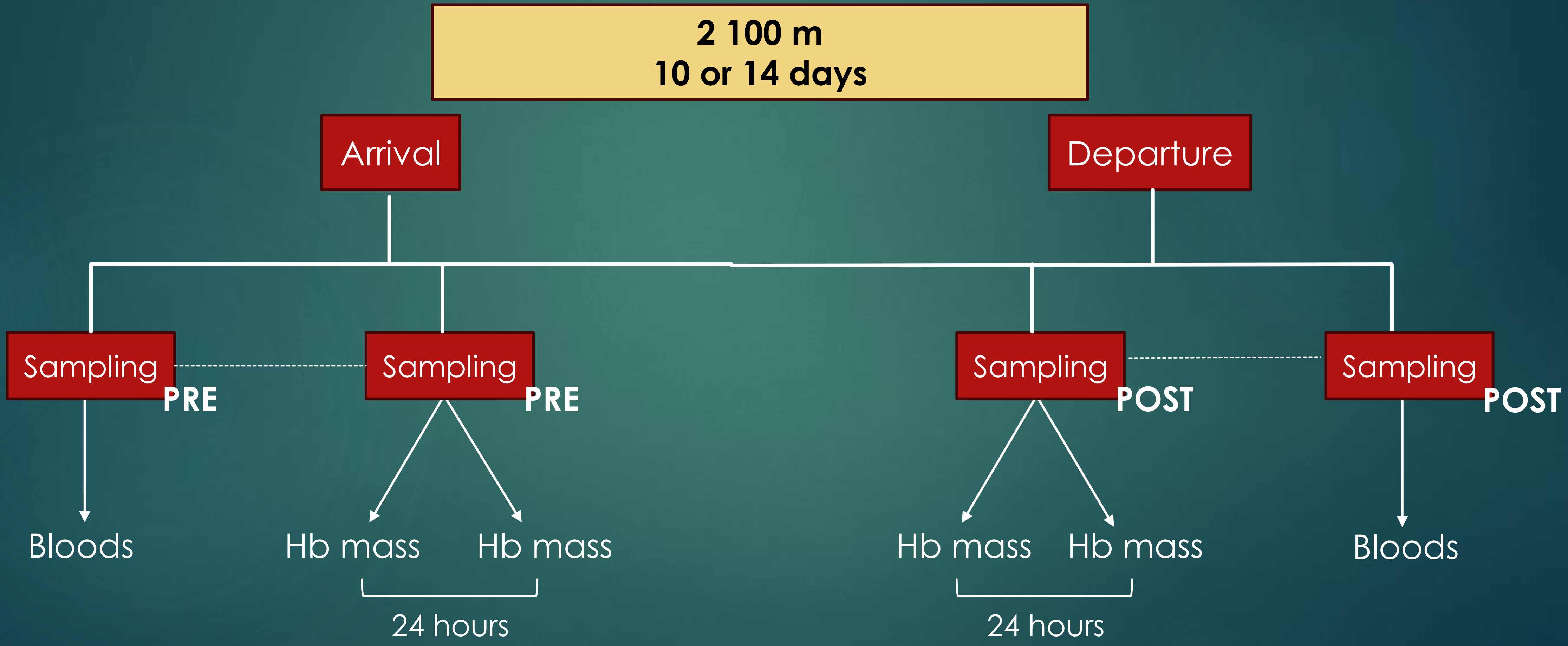
Field Example

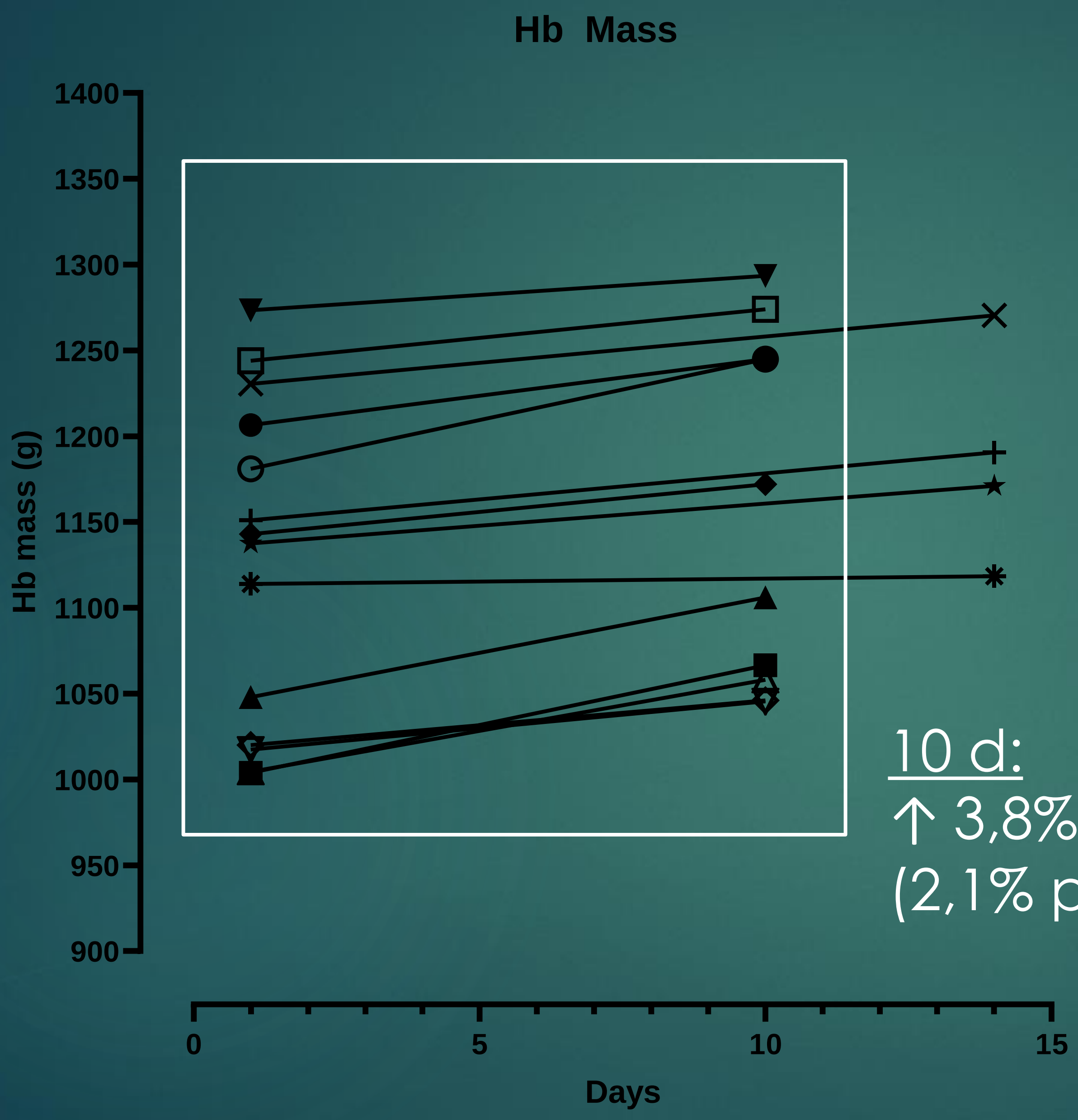
1. The concept of responders and non-responders to altitude is a false dichotomy.
2. If the most important influential variables are controlled for, there should be a universal increase in haemoglobin mass.

Study Characteristics

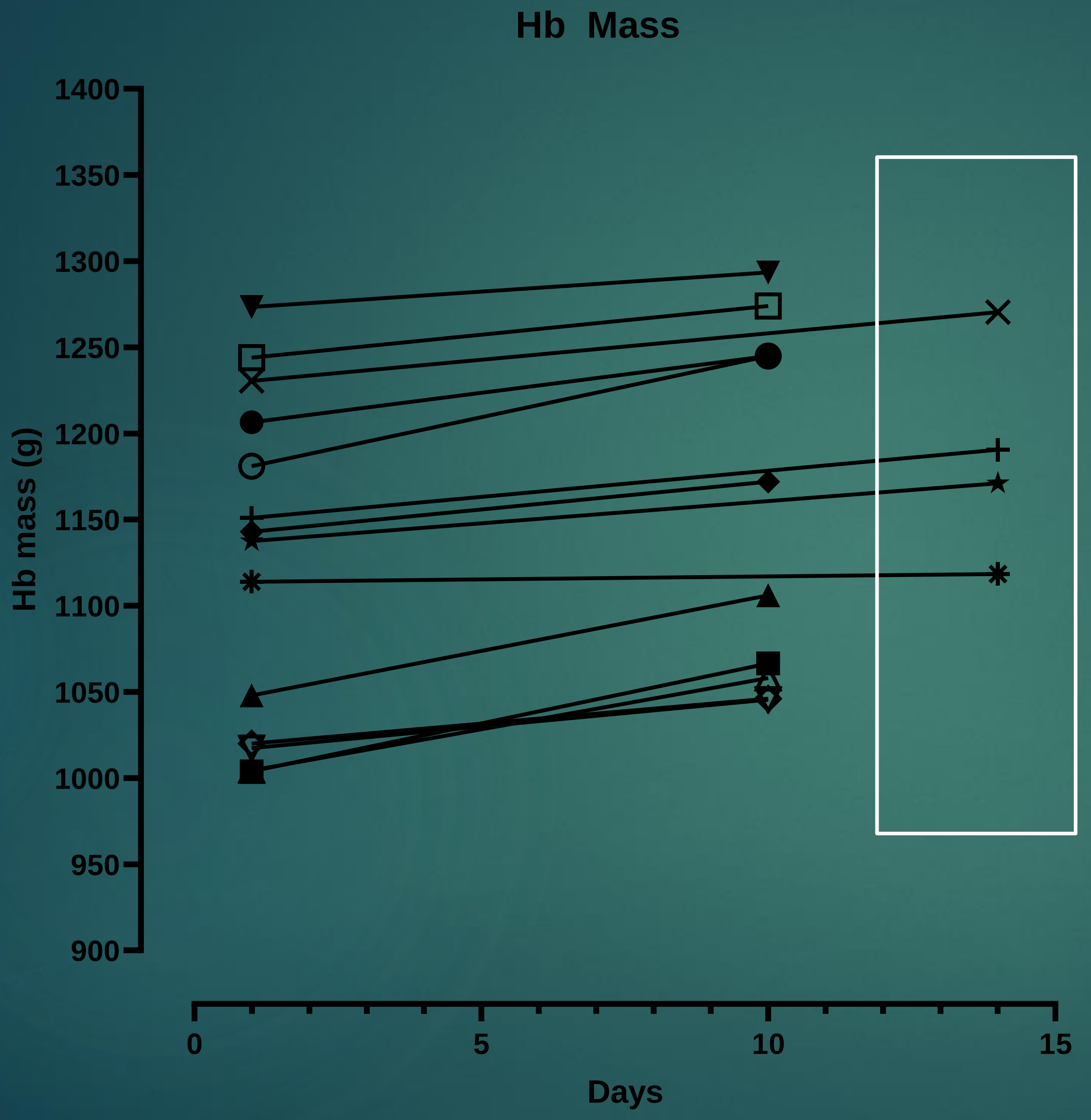
- Sample size: small; 13 WT male professional cyclists
- Location: Sierra Nevada (+-2 100 m)
- Duration:
  - 9 pax: 10 days; +-18 h/day = +-180 hours
  - 4 pax: 14 days; +-18 h/day = +-250 hours
- Controlled variables:
  - Iron status – mean =127 (range: 46-192)
  - Injury/Illness status – **NB** 1 subject with URTI
  - LHTL (no training at altitude)
  - Training load / Fatigue monitoring
  - CHO availability (nutritionist)

Study Design

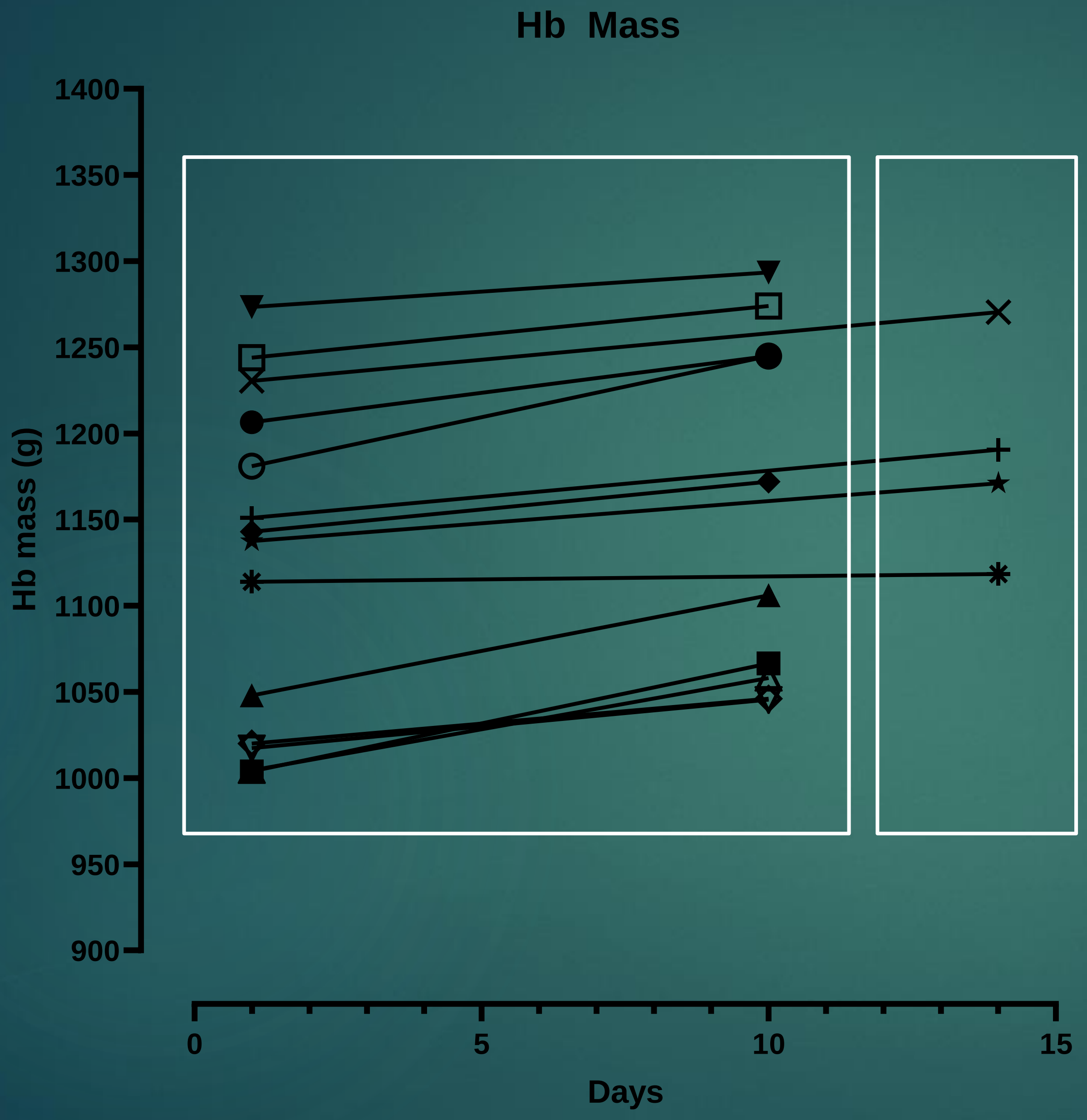




10 d:
↑ 3,8%
(2,1% p/100 h)



14 d:
↑ 2,5% increase
(1,0% p/100 h)



<u>10 d:</u>
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(2,1% p/100 h)

<u>14 d:</u>
↑ 2,5% increase
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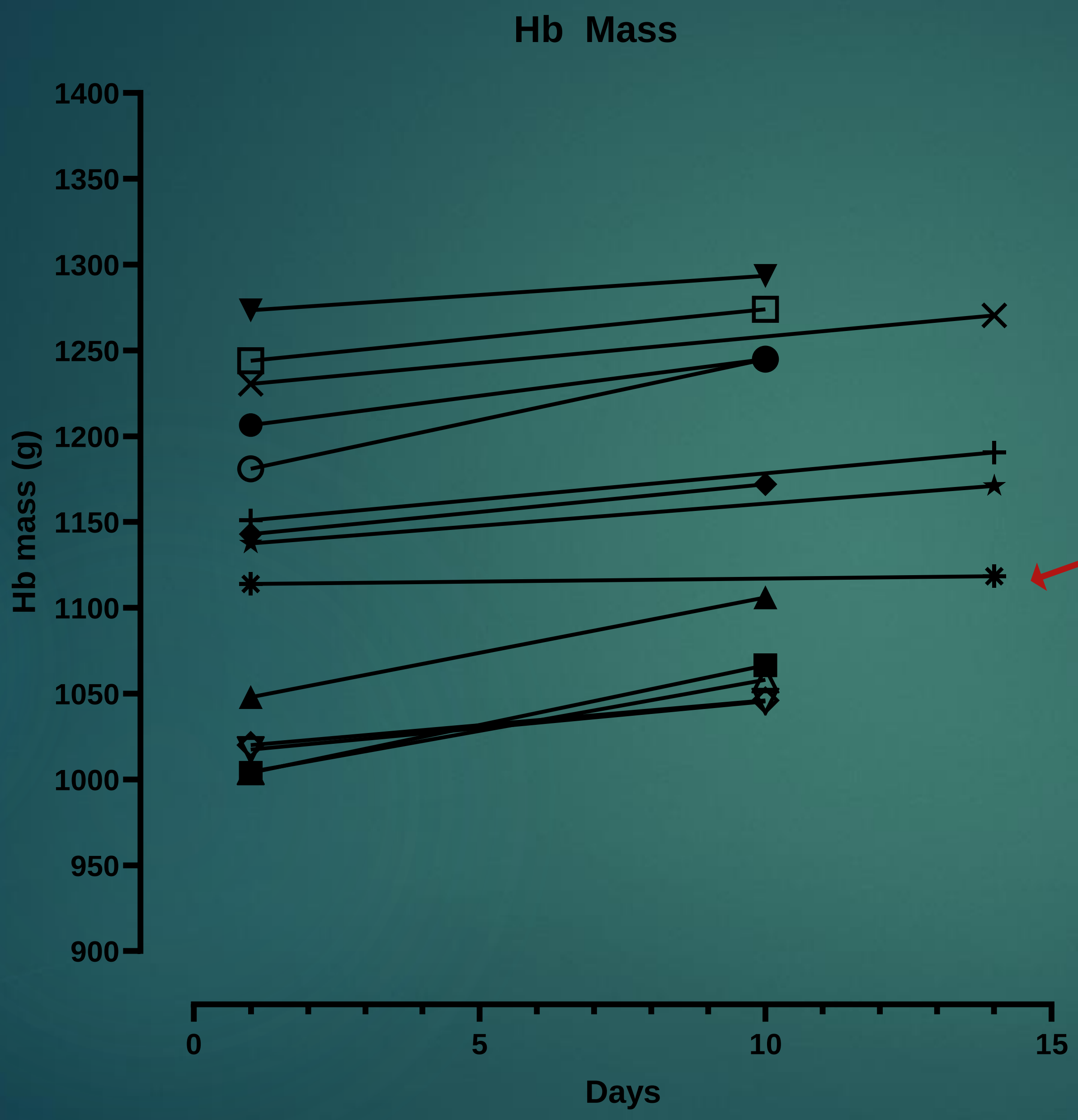
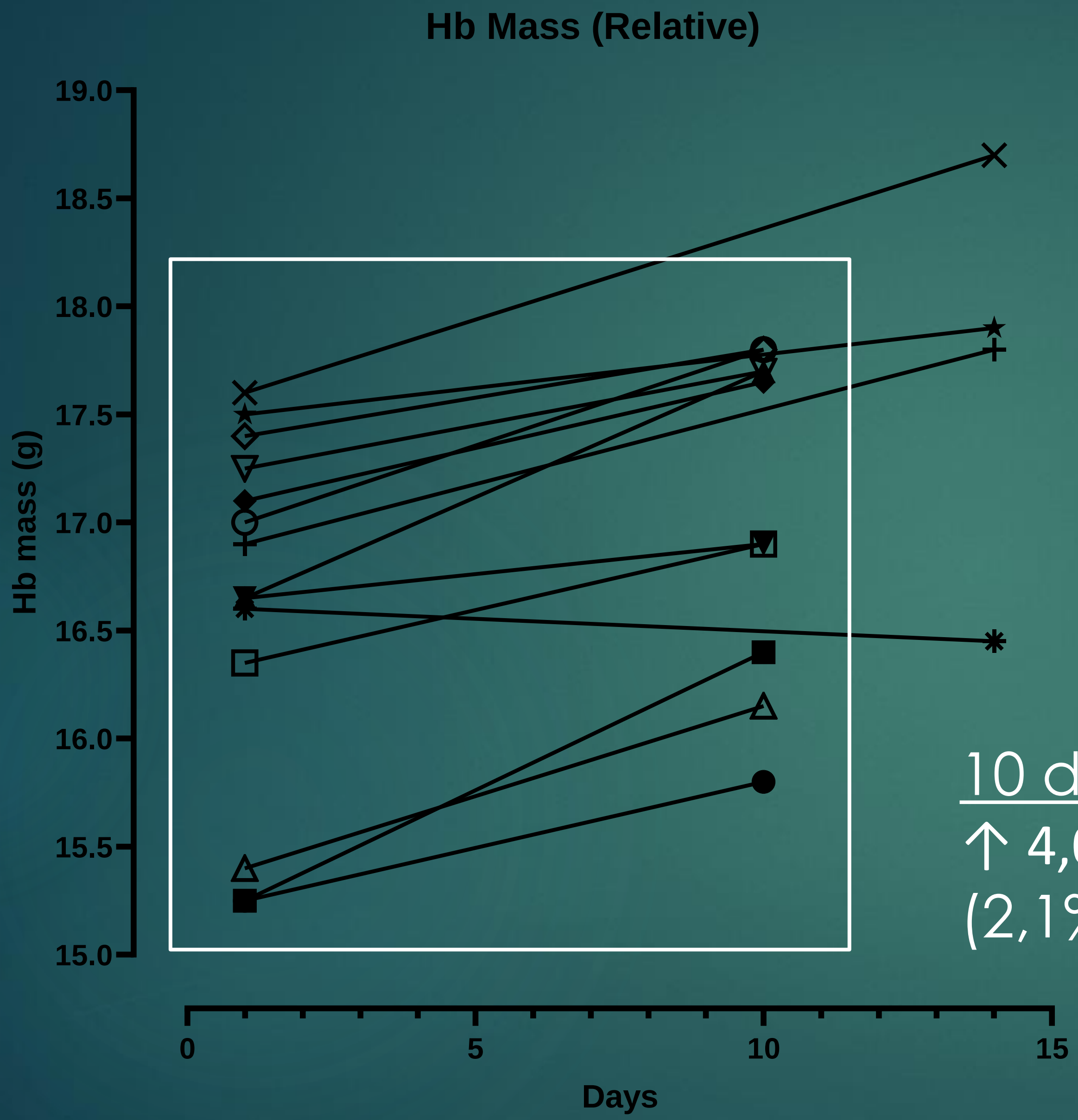


STATIC
(0,4%)

(URTI)



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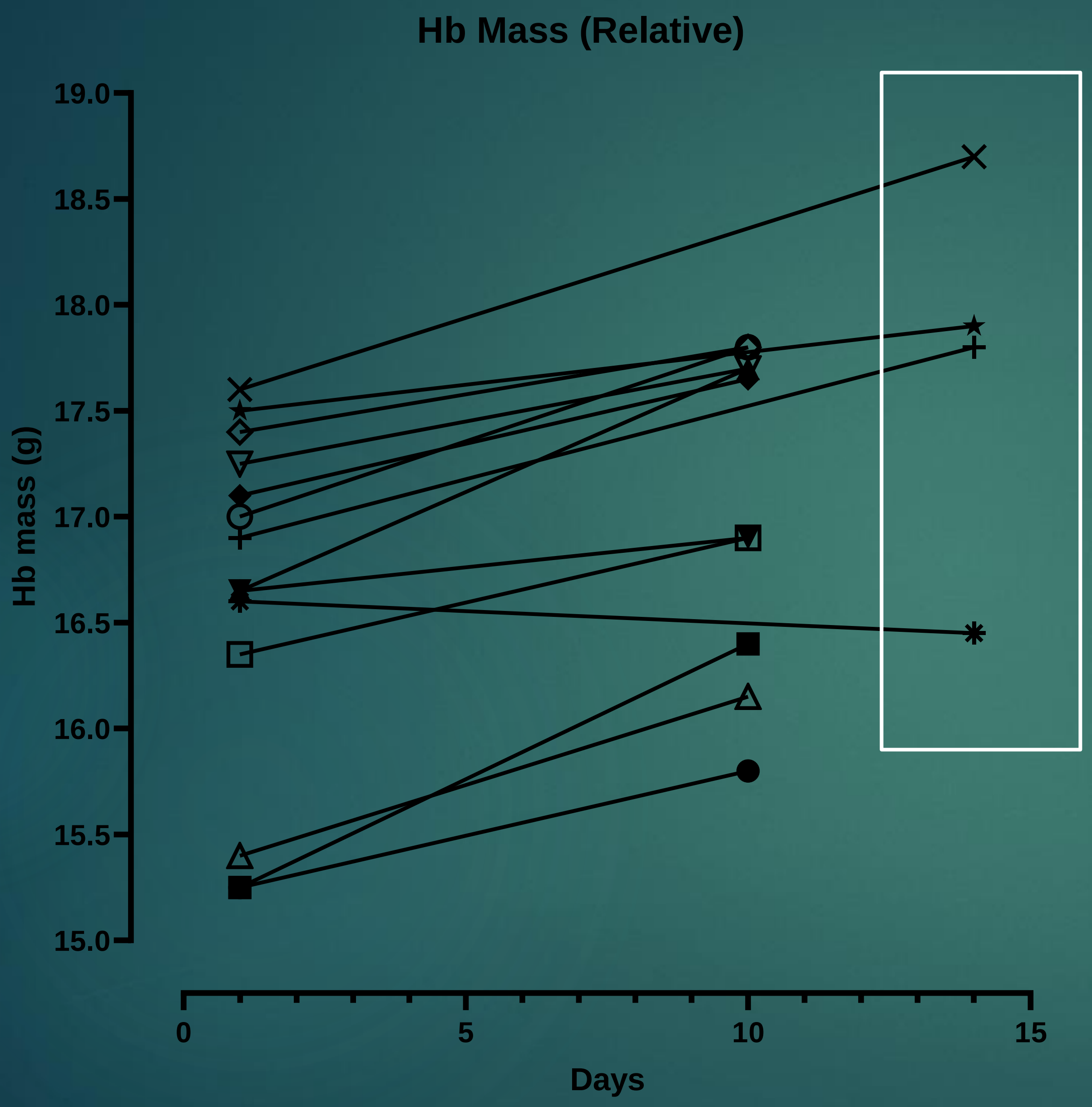
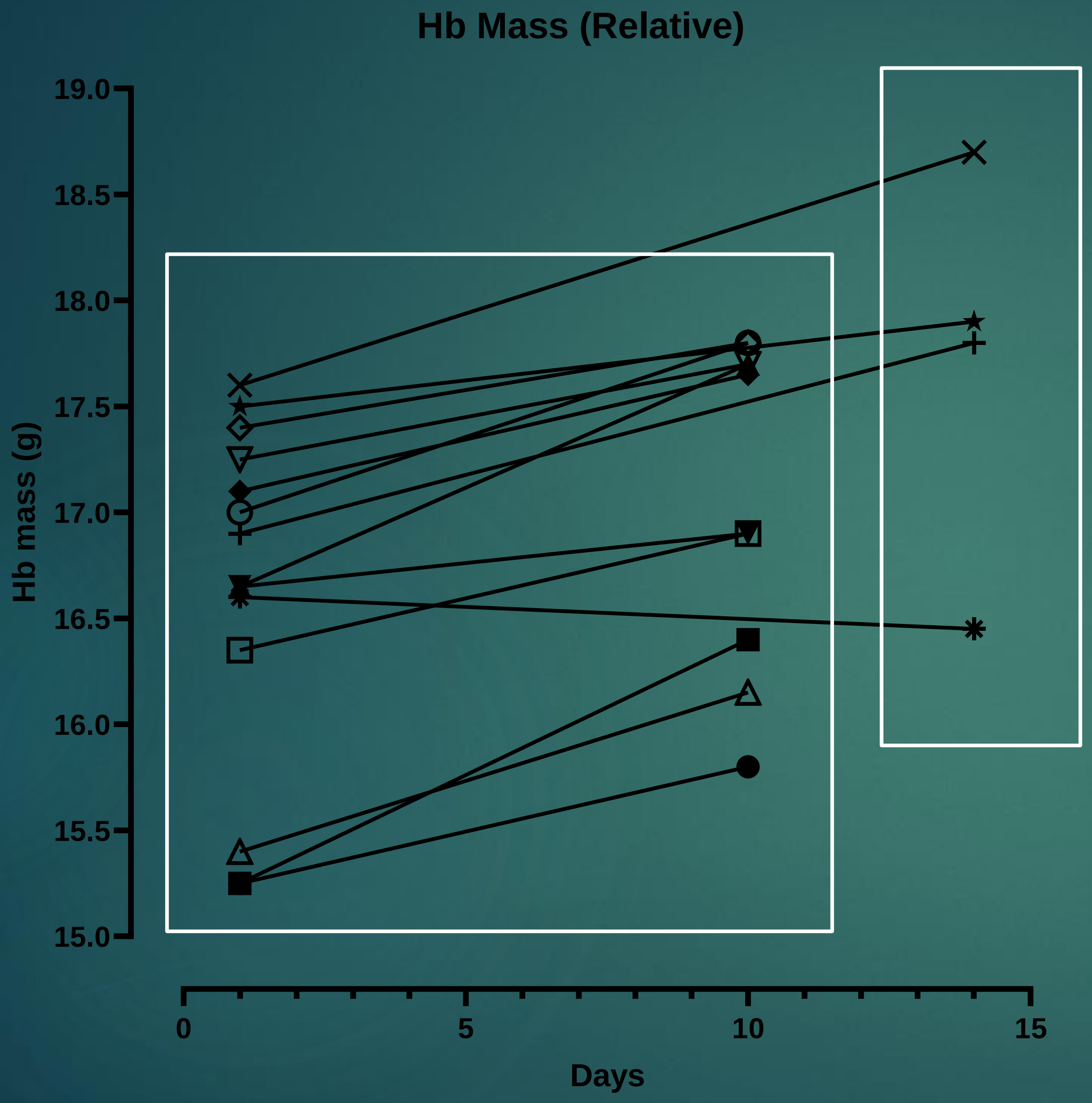
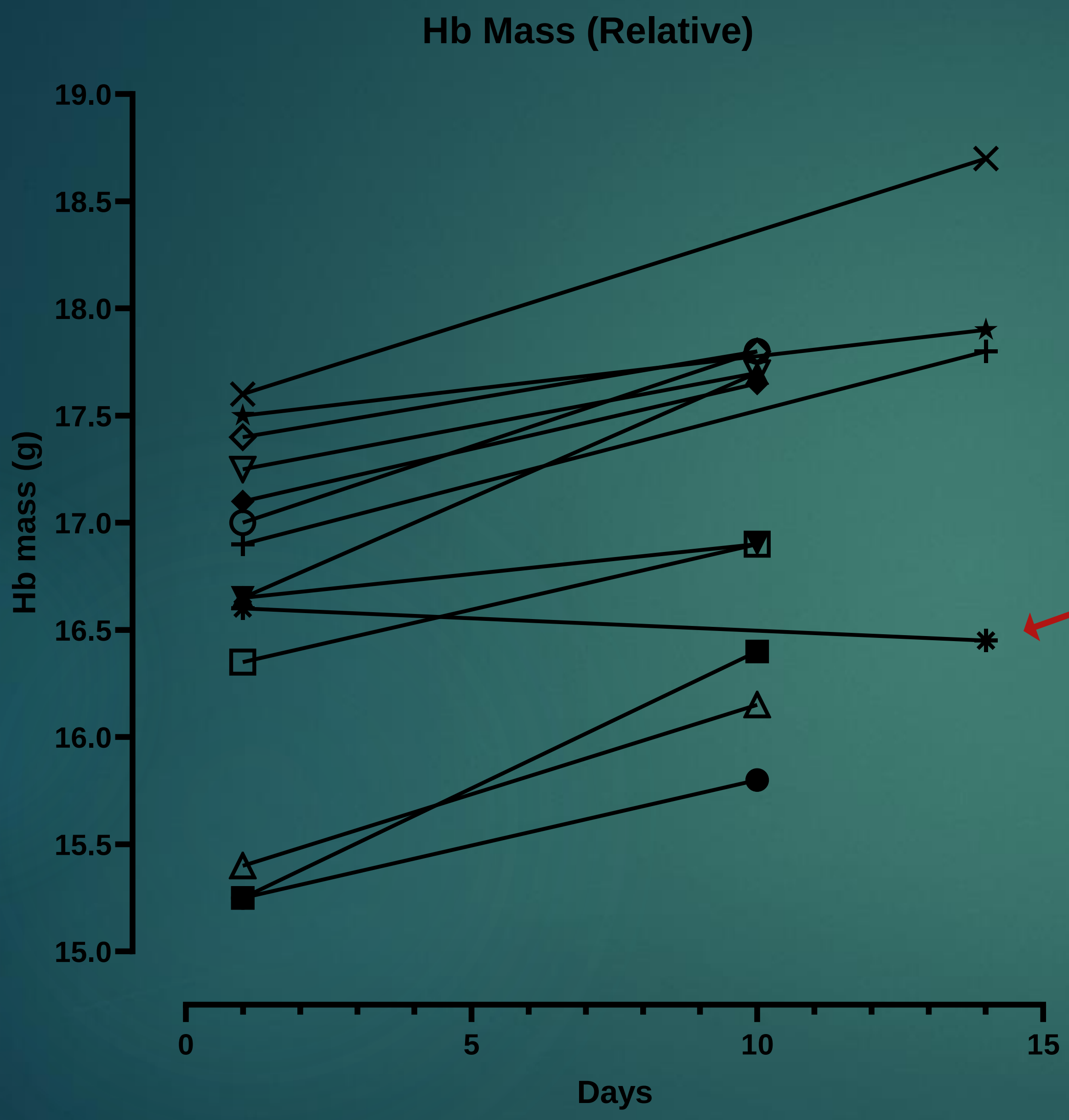


14 d:
↑ 3,2% increase
(1,0% p/100 h)



10 d:
↑ 4,0%
(2,1% p/100 h)

14 d:
↑ 3,2% increase
(1,0% p/100 h)



DECREASE
(-0,9%)

(URTI)

TAKE HOME MESSAGES

- BEFORE
  - Ensure adequate iron stores (ferritin >60)
  - Screen for injury/illness
  - Bloods: Hb, HCT, RCCs, ferritin, CRP, ESR +- EPO/retics%*
- DURING
  - Medical team ↔ Performance team
  - Vulnerability: Continue illness/injury monitoring
- ANTICIPATED RESULTS
  - 1,1% ↑ in Hb mass per 100 hours **BUT…**
  - ≥2 000 m ; ≥21 days ; ≥12 h p/day → ≈300 hypoxic hours **BUT…**

THANK YOU

QUESTIONS?

DR. DAVID A. DE KLERK
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