Symposium
"Dimensions of Performance"
September 3rd, 2005
Berlin, Germany

Dimensions of Performance:
A Symposium on Altitude Training in Berlin
3 September 2005, Berlin

Altitude Training: On Myths and Methods

German Sport University Cologne
Prof. Dr. Joachim Mester,
M. de Marées, Dr. A. Simon, S. Knuth, P. Wahl

Institute of Training Science and Sportinformatics
German Sport University Cologne

Contents

Myths and...

Bob Beamon: Mexico City
2.240m, Oct. 18th, 1968

R. Messner:
Mt. Everest 8.848m, May 8th, 1980

Altitude training as "wonder weapon"

?

"Mountains in the cellar: Ullrich trusts artificial altitude training"

... Methods

Natural altitude: 2320 m

Normobaric chamber: 6.000 m

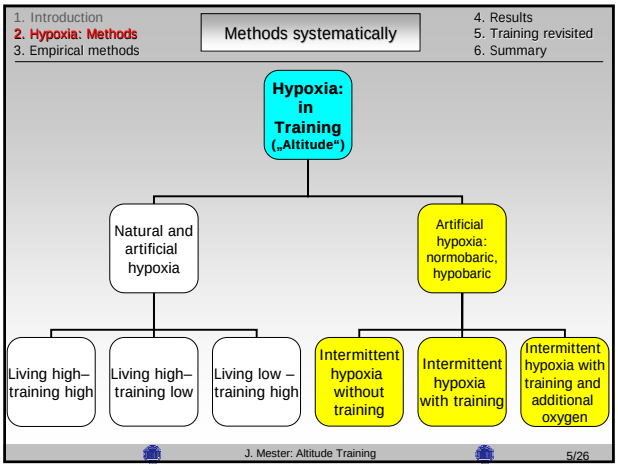
Normobaric room: 3.000 m

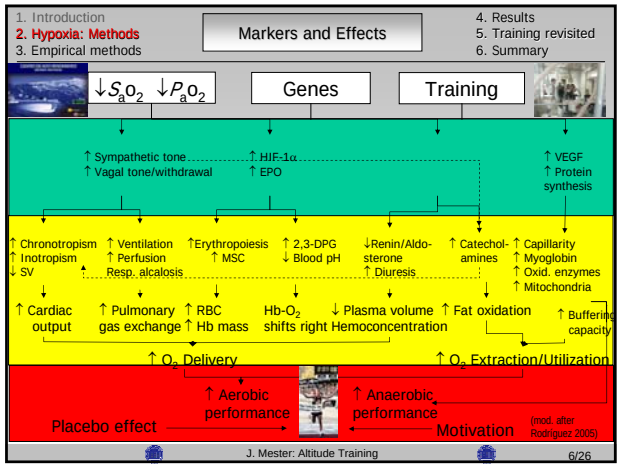
Hypobaric chamber

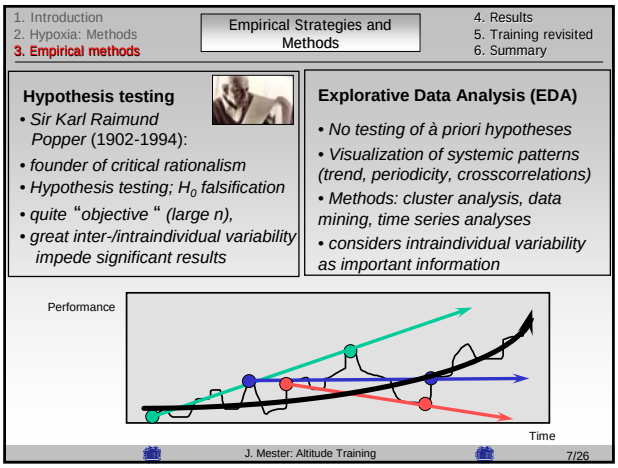
Nitrogen houses

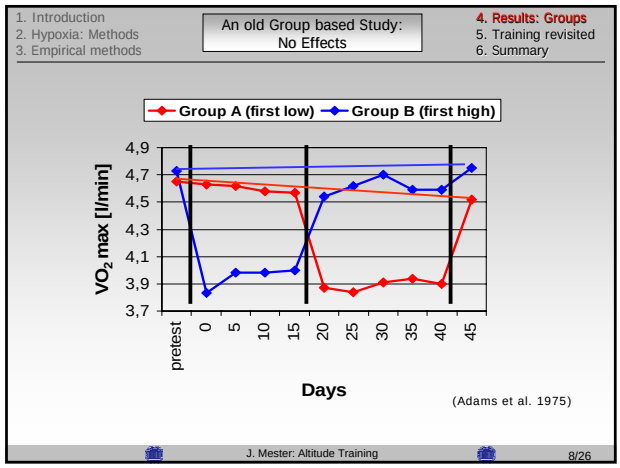
Portable devices

Hypoxic tent

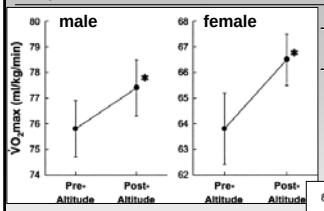

1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Methods systematically
4. Results
5. Training revisited
6. Summary
Hypoxia: in Training („Altitude")
Natural and artificial hypoxia
Artificial hypoxia: normobaric, hypobaric
Living high–training high
Living high–training low
Living low – training high
Intermittent hypoxia without training
Intermittent hypoxia with training
Intermittent hypoxia with training and additional oxygen
J. Mester: Altitude Training
5/26


1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Markers and Effects
4. Results
5. Training revisited
6. Summary
↓SaO2 ↓PaO2
Genes
Training
↑ Sympathetic tone
↑ Vagal tone/withdrawal
↑ HIF-1α
↑ EPO
↑ VEGF
↑ Protein synthesis
↑ Chronotropism
↑ Inotropism
↓ SV
↑ Ventilation
↑ Perfusion
Resp. alcalosis
↑Erythropoiesis
↑ MSC
↑ 2,3-DPG
↓ Blood pH
↓Renin/Aldo-sterone
↑ Diuresis
↑ Catechol-amines
↑ Capillarity
↑ Myoglobin
↑ Oxid. enzymes
↑ Mitochondria
↑ Cardiac output
↑ Pulmonary gas exchange
↑ RBC
↑ Hb mass
Hb-O2 shifts right
↓ Plasma volume
Hemoconcentration
↑ Fat oxidation
↑ Buffering capacity
↑ O2 Delivery
↑ O2 Extraction/Utilization
↑ Aerobic performance
↑ Anaerobic performance
Placebo effect
Motivation
(mod. after Rodriguez 2005)
J. Mester: Altitude Training
6/26

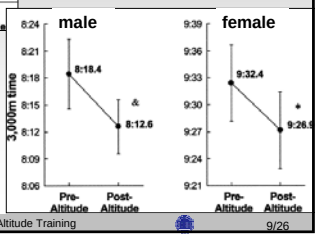

1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Empirical Strategies and Methods
4. Results
5. Training revisited
6. Summary
Hypothesis testing
• Sir Karl Raimund Popper (1902-1994):
• founder of critical rationalism
• Hypothesis testing; H0 falsification
• quite "objective " (large n),
• great inter-/intraindividual variability impede significant results
Explorative Data Analysis (EDA)
• No testing of à priori hypotheses
• Visualization of systemic patterns (trend, periodicity, crosscorrelations)
• Methods: cluster analysis, data mining, time series analyses
• considers intraindividual variability as important information
Performance
Time
J. Mester: Altitude Training
7/26


1. Introduction
2. Hypoxia: Methods
3. Empirical methods
An old Group based Study: No Effects
4. Results: Groups
5. Training revisited
6. Summary
Group A (first low)
Group B (first high)
VO2 max [l/min]
4,9
4,7
4,5
4,3
4,1
3,9
3,7
pretest
0
5
10
15
20
25
30
35
40
45
Days
(Adams et al. 1975)
J. Mester: Altitude Training
8/26

A new Group based Study: Positive Effects



- 22 runners (internat. level): 14 male, 8 female
- 27 days living at 2500m; „individual" high-intensity training at 1250m



Performance : ↑
VO_2max : ↑
EPO, Hb : ↑

(Stray-Gundersen, Chapman, Levine 2001)

Living high and Training high - Controlled Studies

Reference	Design	Time post-altitude, performance test, and outcome (+ = better, - = worse)		
Controlled Studies[a]				
Gore et al., 1997	13+8 runners, 28 d at 1740 m	?	VO2max	+1.0%
			3.2-km run	-0.6%
	8+8 runners, 28 d at 1300 m	?	VO2max	+1.1%
			3.2-km run	+0.2%
Levine & Stray-Gundersen, 1997	13 + 13 runners, 28 d at 2500 m	4 d	VO2max	+4.9%*
		3-21 d	5-km run	+2.5%*
Burtscher et al., 1996	10+12 runners, 12 d 2300 m	3&16 d	VO2max	+1.4%&8.7%*
Rusko et al., 1996	14+7 skiers, 18-28 d at 1600-1800 m	<8 d	VO2max	-3.1%
			anaer. power	-7.5%*
Telford et al., 1996	9 + 9 runners, 28 d mainly at 1800 m	<8 d	VO2max	+3.0%
			~3-min run	-0.6%[b]
			3.2-km run	0.0%
Martino et al., 1995	20+13 swimmers, 21 d at 2800 m	?	100-m swim	+~4%*
			Anaer. tests	+>3%*

(Baker, Hopkins 1998)

Living high and Training high - Controlled Studies

Martino et al., 1995	20+13 swimmers, 21 d at 2800 m	?	100-m swim	+~4%*
			Anaer. tests	+>3%*
Jensen et al., 1993	9 + 9 elite rowers (non-random assignment), 21 d at 1800 m	?	VO2max	-4%
			6-min row	-3%
Levine & Stray-Gundersen, 1992	9 + 10 runners, 28 d at 2500-3000 m	?	VO2max	-0.7%
			5-km run	+1.7%
Karvonen et al., 1986	3 + 4-6 sprinters, 21 d at 1850 m	?	VO2max	+3.4%
			peak run speed	+4.6%
			~1-min run to exhaustion	-1.1%[b]
			30-m run	-0.2%
			jumps	-6.1% to +8.8%
Rahkila & Rusko, 1982c	6 skiers + 8 skiers/runners, 11 d at 2600 m	?	VO2max	"small reduction"
			1-min cycle	"not significant"
Adams et al., 1975	6 + 6 runners (crossover), 20 d at 2300 m	1 d	VO2max	-2.8%
		3 d	2-mile run	+1.3%

(Baker, Hopkins 1998)

Living high – Training low: Controlled Studies

Levine & Stray-Gundersen, 1997	13 + 13 runners, 28 d at 2500/1250 m	4 d	VO2max	+5.4%*
		3-21 d	5-km run	+4.3%*
Stray-Gundersen & Levine, 1997	13 runners, 28 d at 2500/2700/1250 m ("high-high-low")	4 d ?	VO2max	0.0% relative to high-low
		3 d ?	5-km run	+0.2% relative to high-low
Nummela et al., 1996	6 + 6 runners, 10 d in nitrogen house set to 2200 m	<8 d	peak running speed	+0.4%
			400-m run	+1.0%* control not stated
Levine et al., 1991	6 + 3 runners, 28 d at 2500/1300 m	?	VO2max	+3.1%*
			5-km run	+2.3%

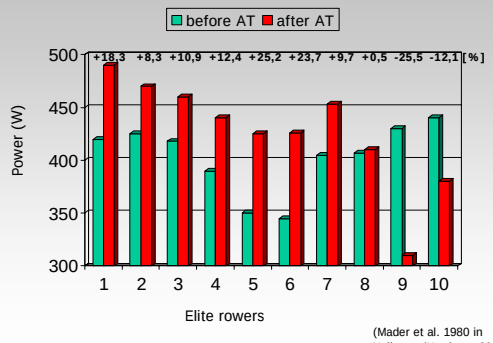
(Baker, Hopkins 1998)

Living high – Training Low: Uncontrolled Studies

Chapman et al., 1998	22 elite runners, 28 d at 2500/2700/1250 m ("high-high-low")	3 d	3-km run	+1.2%*
Mattila & Rusko, 1996	5 cyclists, 11 d in nitrogen house set to 3000 m	5 d	?-km cycle	+3.7%
Stray-Gundersen & Levine, 1994	6 runners, 28 d at 2500/1250 m	0 & 14 d	VO2max	-3.6% & -4.0%
			5-km run	+0.9% & -1.3%
			~3-min run to exhaustion	+1.0% & 0.0% b
Chick et al., 1993	5 subjects, 6 weeks of hypoxic cycling at 1600 m	0 d	19-min cycle	+2.6%*
			~6-min cycle to exhaustion	+1.6% *

(Baker, Hopkins 1998)

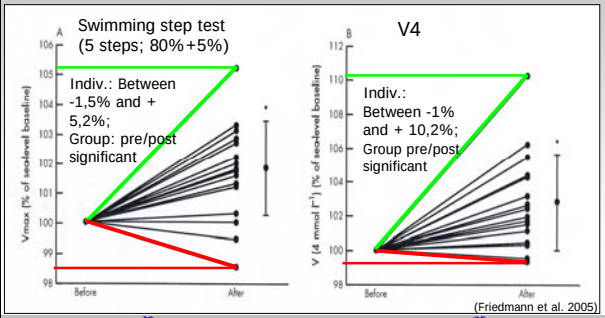
Individual Results: Rowers



(Mader et al. 1980 in Hollmann/Hettinger 2000)

Individual Results: Swimmers

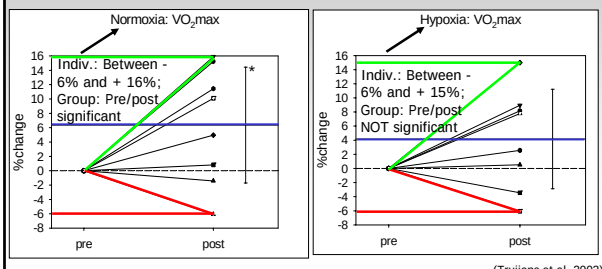
- 16 junior swimmers (intern. Niveau), 9 female, 7 male
- acute 4hrs normobaric hypoxia (2.500m);
- 3 weeks natural altitude, 2300 m (SH-TH)



(Friedmann et al. 2005)

Individual Results: Swimmers

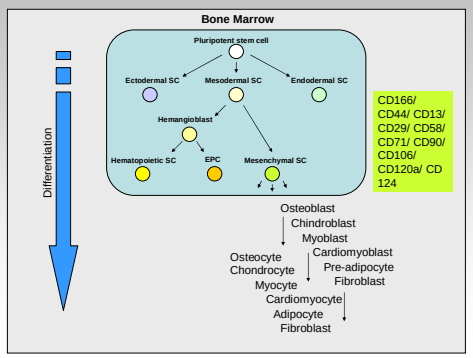
- 18 trained swimmers (M & F)
- 100/400-m time trial (performance markers)
- submax and maximal VO_2 (swimming flume)
- 4 weeks interval training



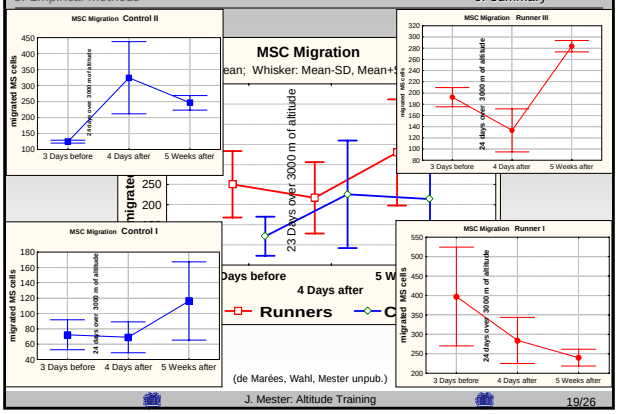
(Truijens et al. 2003)

Subjects
5 endurance runners
3 control (sedentary TV-staff)
Age
28,9 ± 5,4 years
VO_{2max} (running 2700m a.s.l.)
53,4 ± 10,8 ml/min/kg
Period of study
4.3. – 2.4.2005
Running distance / runner / day
20 ± 18 km
Altitude
0 - 4600 m
Training
sleep high - train low
sleep low – train high

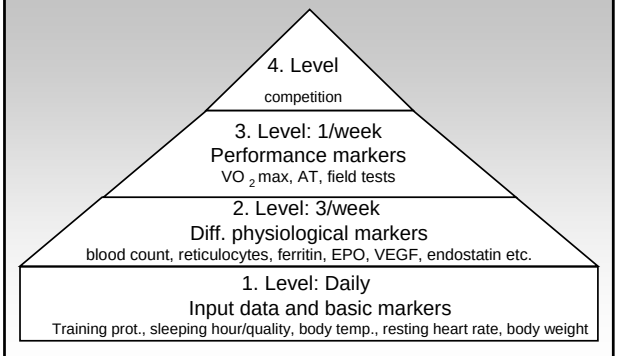
(de Marées, Bloch, Wahl, Mester 2005)

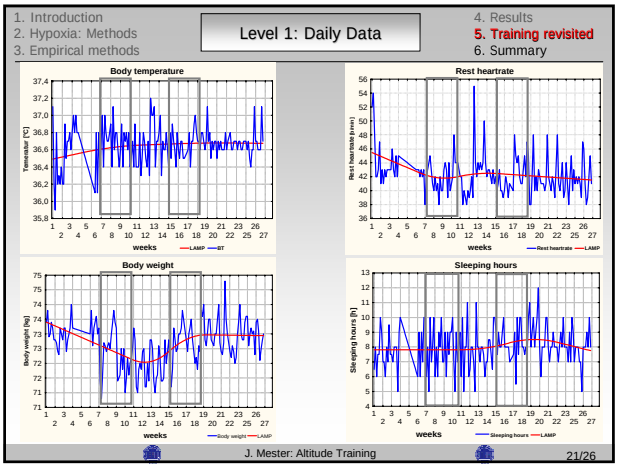


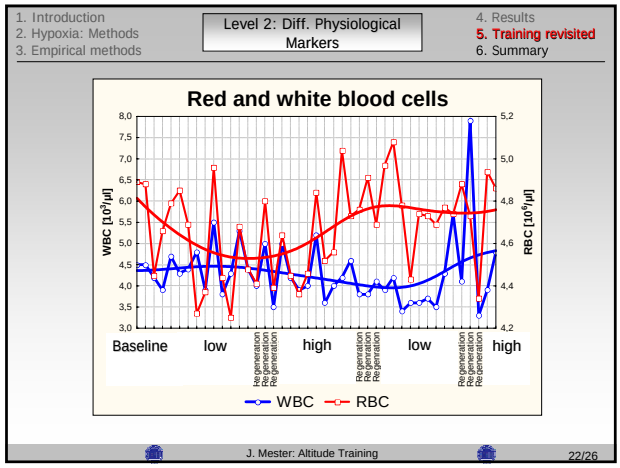
(de Marées, Wahl, Mester 2005)

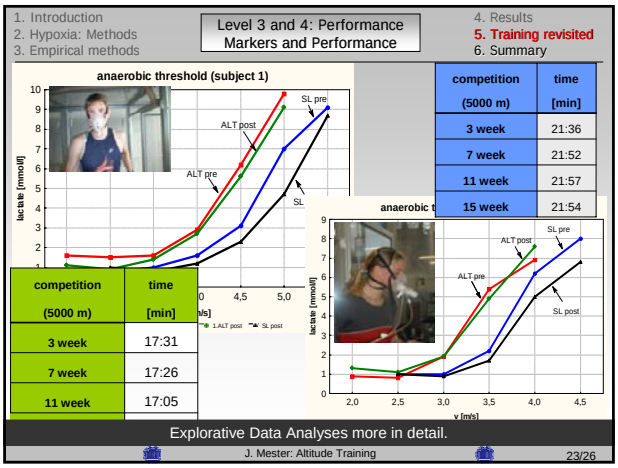


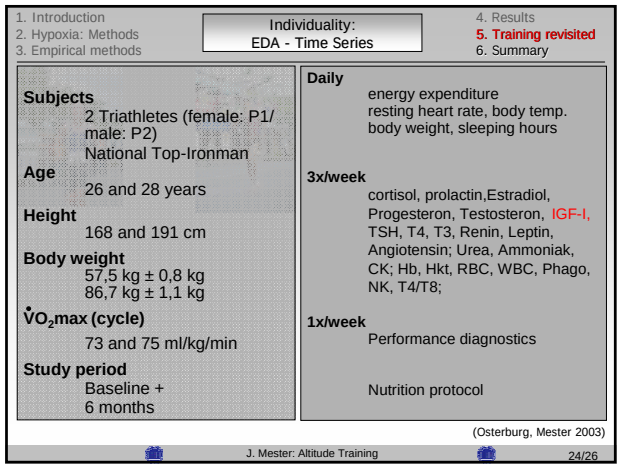
(de Marées, Wahl, Mester unpub.)

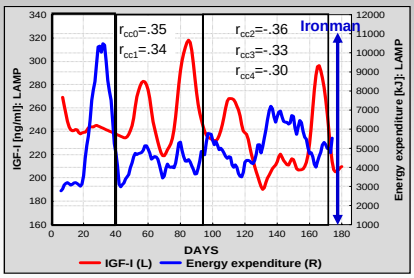



1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Level 1: Daily Data
4. Results
5. Training revisited
6. Summary
Body temperature
Rest heartrate
Body weight
Sleeping hours
weeks
J. Mester: Altitude Training
21/26


1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Level 2: Diff. Physiological Markers
4. Results
5. Training revisited
6. Summary
Red and white blood cells
WBC [10³/µl]
RBC [10⁶/µl]
Baseline
low
high
low
high
Regeneration
WBC
RBC
J. Mester: Altitude Training
22/26


1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Level 3 and 4: Performance Markers and Performance
4. Results
5. Training revisited
6. Summary
anaerobic threshold (subject 1)
lactate [mmol/l]
ALT post
ALT pre
SL pre
SL
competition (5000 m)
time [min]
3 week 21:36
7 week 21:52
11 week 21:57
15 week 21:54
competition (5000 m)
time [min]
3 week 17:31
7 week 17:26
11 week 17:05
Explorative Data Analyses more in detail.
J. Mester: Altitude Training
23/26


1. Introduction
2. Hypoxia: Methods
3. Empirical methods
Individuality: EDA - Time Series
4. Results
5. Training revisited
6. Summary
Subjects
2 Triathletes (female: P1/ male: P2)
National Top-Ironman
Age
26 and 28 years
Height
168 and 191 cm
Body weight
57,5 kg ± 0,8 kg
86,7 kg ± 1,1 kg
V̇O2max (cycle)
73 and 75 ml/kg/min
Study period
Baseline +
6 months
Daily
energy expenditure
resting heart rate, body temp.
body weight, sleeping hours
3x/week
cortisol, prolactin,Estradiol, Progesteron, Testosteron, IGF-I, TSH, T4, T3, Renin, Leptin, Angiotensin; Urea, Ammoniak, CK; Hb, Hkt, RBC, WBC, Phago, NK, T4/T8;
1x/week
Performance diagnostics
Nutrition protocol
(Osterburg, Mester 2003)
J. Mester: Altitude Training
24/26



(Osterburg, Mester 2003)

Meta-analyses of more than 100 international studies in the last 40 years and own results show:

✓ Practical experiences and also controlled studies indicate performance enhancement effects, other do not.

✓ Acute and chronic hypoxia induce well-known physiological effects in gas exchange, hematology etc.

✓ Performance enhancement MAY occur. It is, however, in onset, magnitude and duration very individual.

✗ Re-adaptation to sea level is quite rapid, the duration of positive effects is scientifically unclear.

✗ The effects of all options live high/low – train high/low are not sufficiently proven.

✗ Criteria for individual input (training load at altitude) are often insufficient: High-low responders, early-late responders.