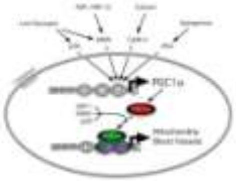
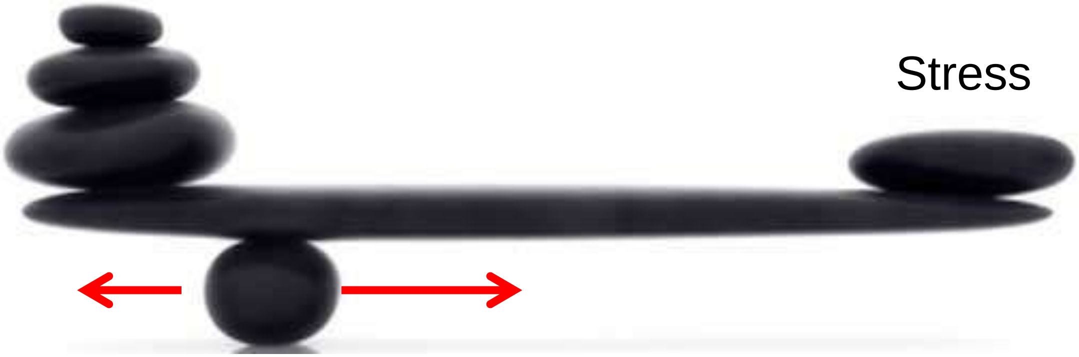
From polarized to optimized?
Moving towards 2025

Stephen Seiler PhD
Faculty of Health and Sport Sciences
University of Agder, Kristiansand, Norway
Norwegian Olympic Federation

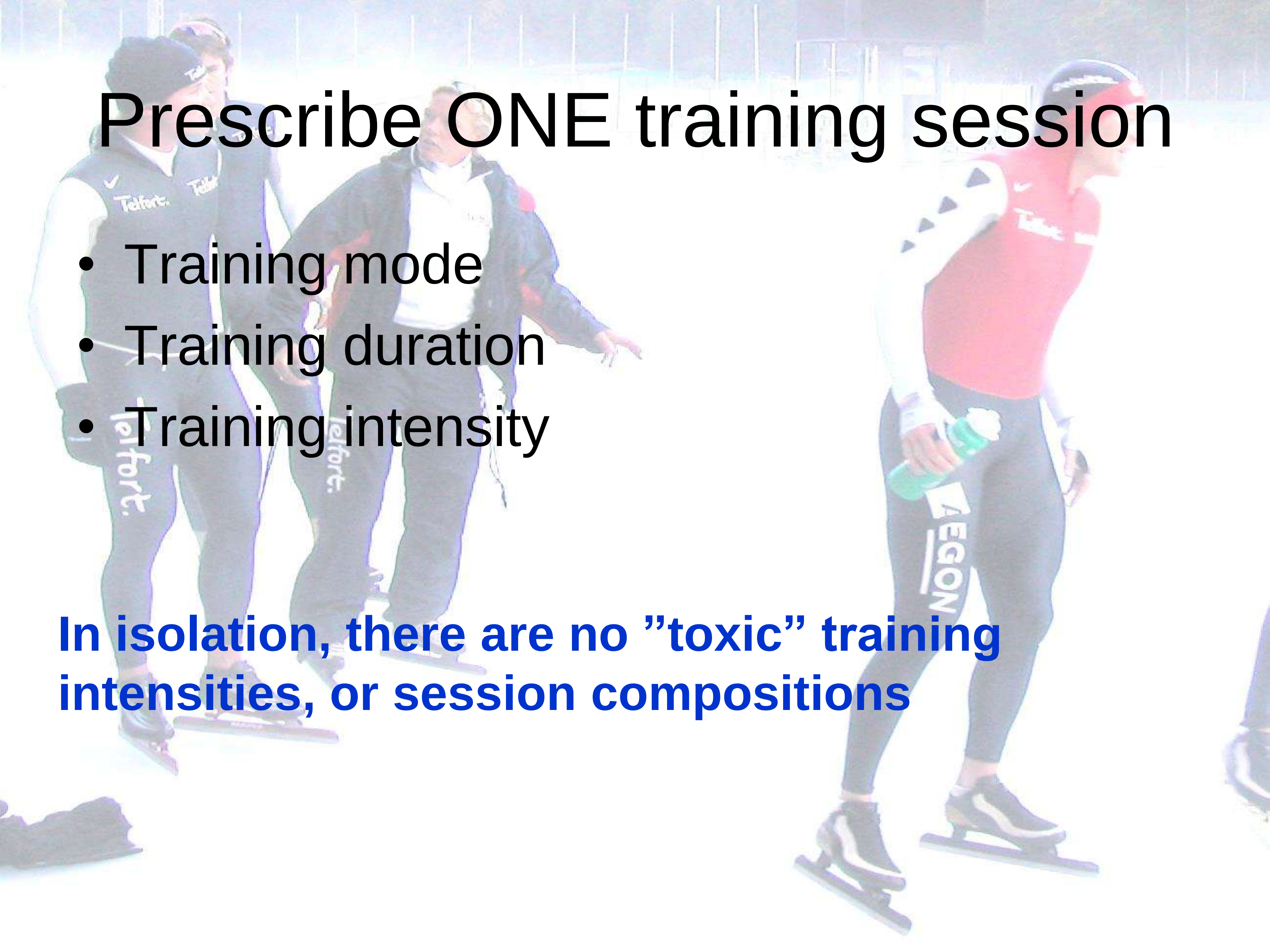




Stimulus

Stress

(Training characteristics)



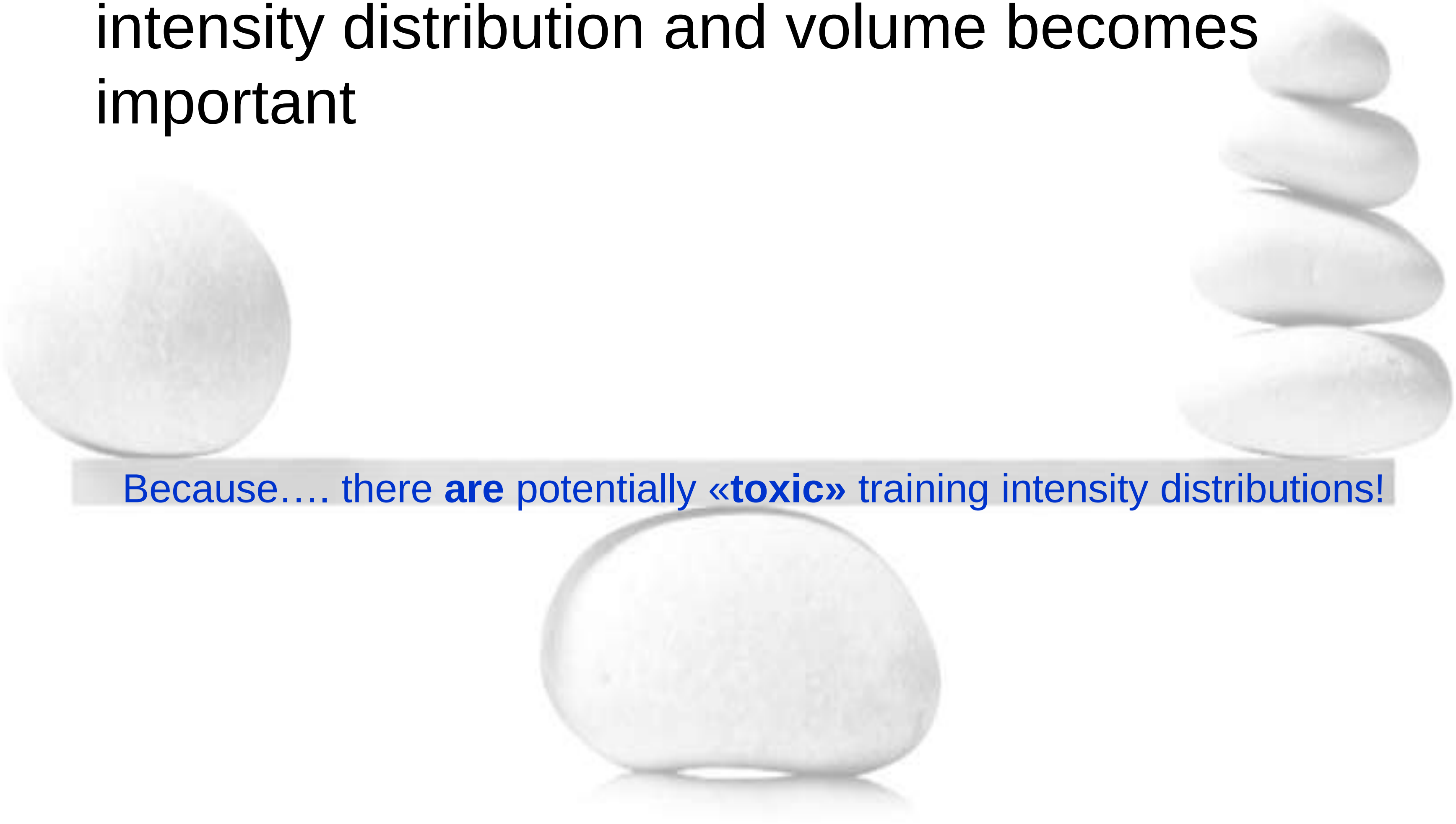
Prescribe ONE training session

- Training mode
- Training duration
- Training intensity

In isolation, there are no ”toxic” training intensities, or session compositions

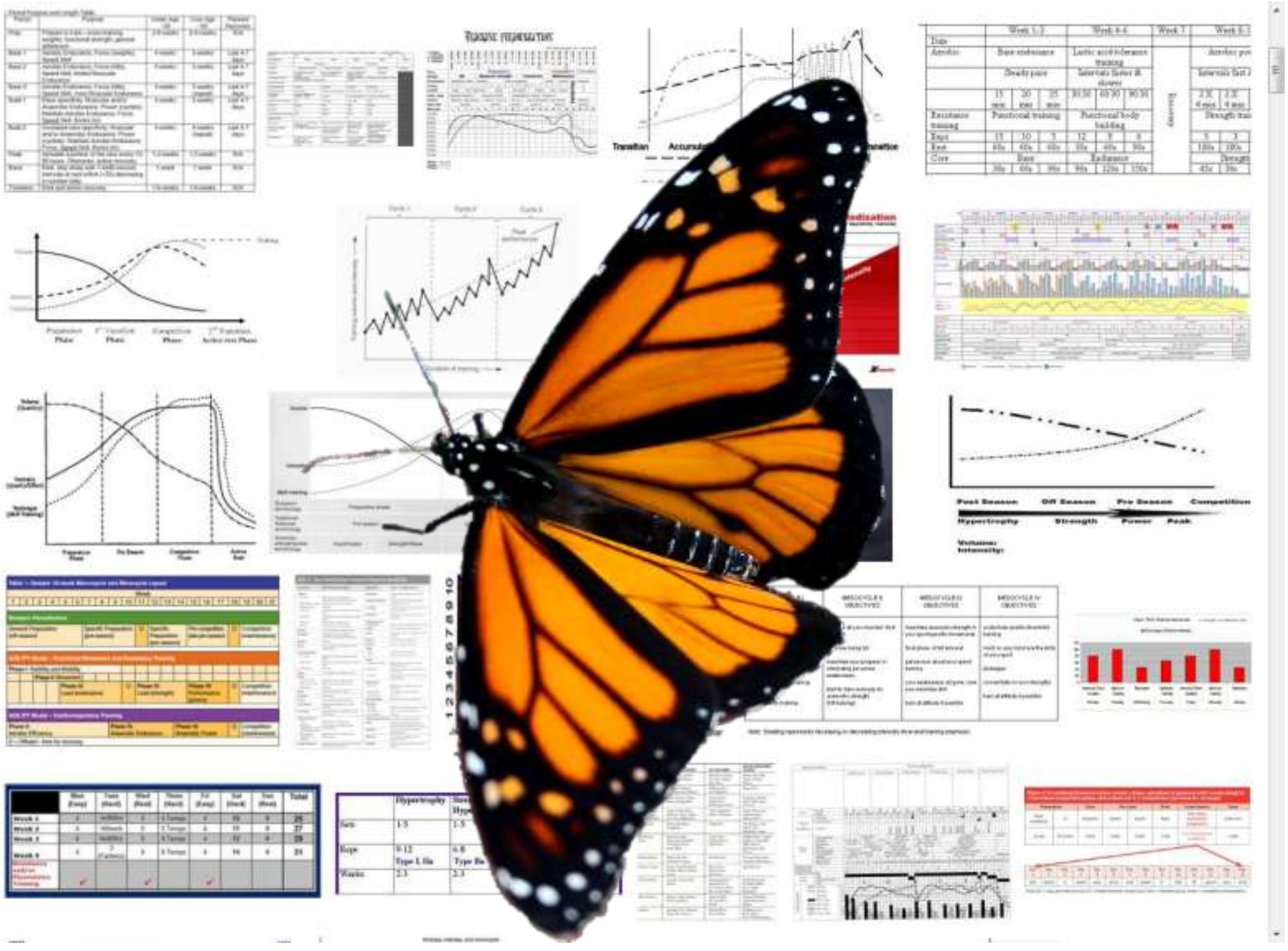
Prescribe ONE (typical) WEEK

- Balancing **stress** load and **stimuli** magnitude – intensity distribution and volume becomes important



Because…. there **are** potentially «**toxic**» training intensity distributions!

Prescribe 12 (building) WEEKS


Transition
Post Season
Off Season
Pre Season
Competition
Hypertrophy
Strength
Power
Peak
Volume:
Intensity:
1 2 3 4 5 6 7 8 9 10

How much control over the basic training outcome do we have at the individual level?

Individual variation that is «genetic» and **non-responsive** to alterations in training prescription

The bigger **this** box, the less fun our job!

Individual variation that is **responsive** to adjustments in training prescription

Variation is large, but how much of it can be «corrected»?

Generalizable effects related to **periodization** characteristics **within** a best practice framework?

Small effects?- reality may not live up to the fancy lingo

Generalizable effects due to **basic framework** of intensity distribution and volume load?

15 years of work suggests this has a **substantial effect**

Endurance training intensity zones

Intensity Zone	Heart rate (% max)	Lactate (mmol·L^{-1})	Typical effective work time within zone
1	60-72	0.8-1.5	1-6 h
2	72-82	1.5-2.5	1-3 h
3	82-87	2.5-4.0	50-90 min
4	88-93	4.0-6.0	30-60 min
5	94-100	6.0-10.0	15-30 min

Table 1. A 5-zone intensity scale to prescribe and monitor training of endurance athletes This scale is typical of intensity-zone scales used for endurance training prescription and monitoring (From Norwegian Olympic Federation). Blood lactate concentration references are based on hemolyzed blood (as acquired from the Lactate Pro device). Effective work time within zone for a 6 x 4 min interval session with 2 minute rest periods would be 24 minutes.

100% HR peak

INTENSIVE Intensity Zone, interval based, Accumulated minutes, severe exertion, accumulation fatigue

HIT Intensity Pole at about 90% HR peak

86% HR peak ~4mM blood lactate

Threshold Intensity Zone

78% HR peak ~2mM blood lactate

EXTENSIVE Intensity Zone, continuous,
hours, moderate exertion, depletion fatigue

«LIT Intensity Pole» at about 65-68% VO_2 peak, 70-72% HR peak

60-65% HR peak

3 experiences that catalyzed my work on intensity distribution and PTM

1. A well trained athlete **walks** up a steep forest hill-when they could have run!

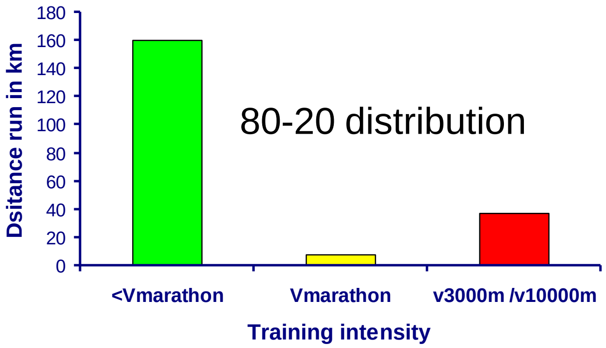
Discipline
The difference between good and great.

Enforce Intensity discipline

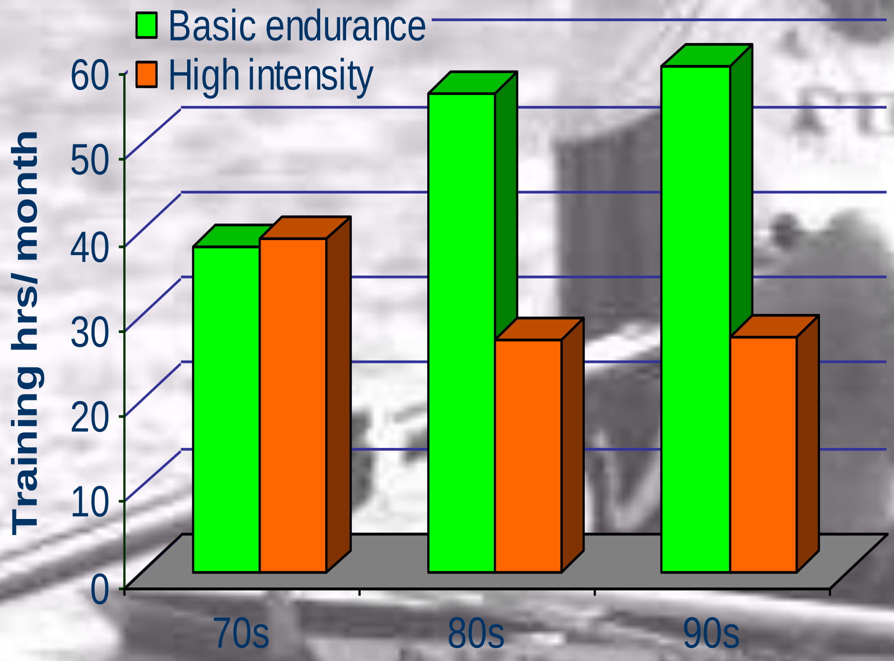
2. A national team coach of XC legends says LT training is too stressful for the benefit it induces

Minimize the middle

3. I review a paper on the training of elite Kenyan marathoners and recalculate the data….



Training Intensity Distribution International Rowing Medalists

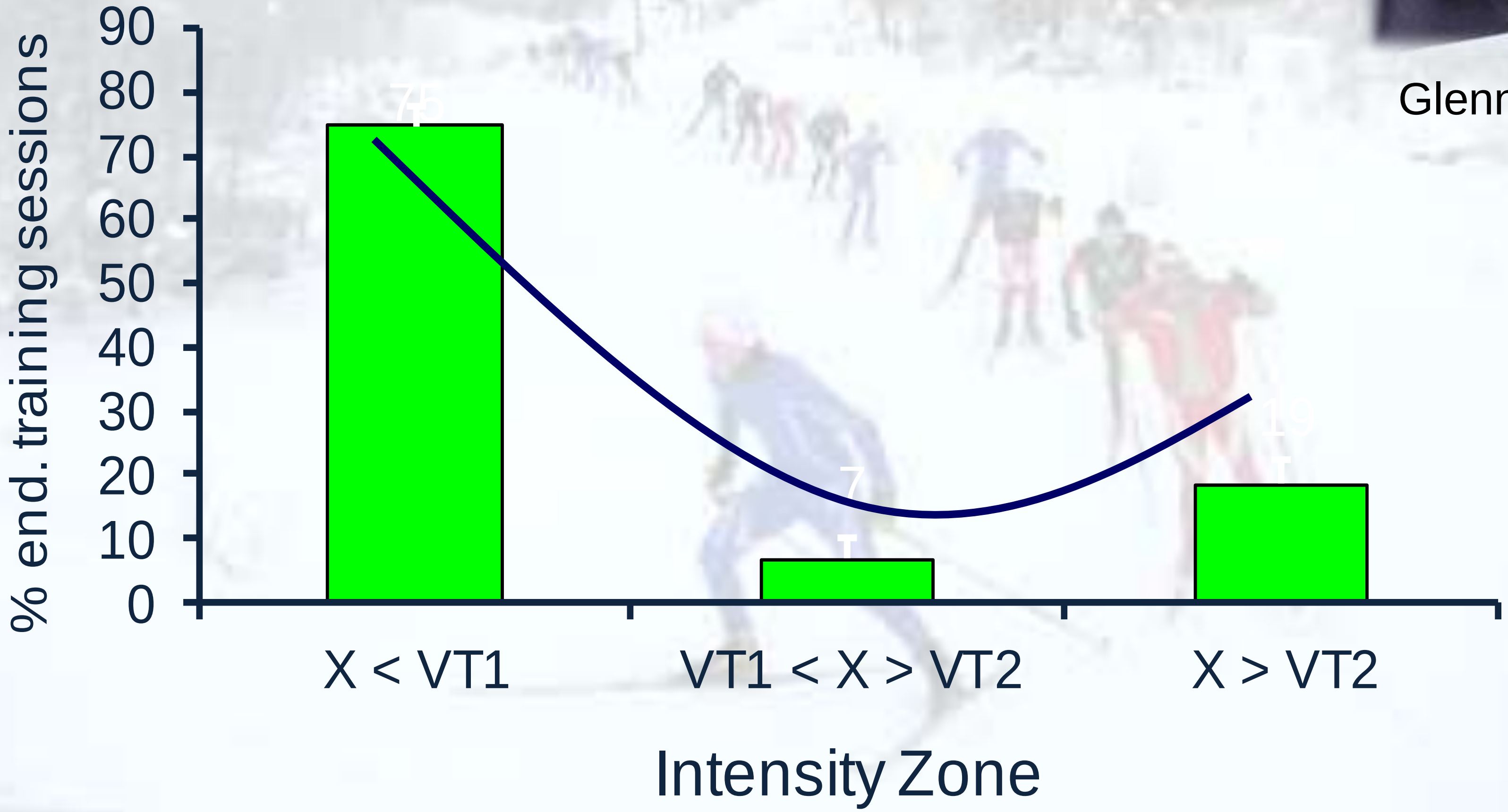


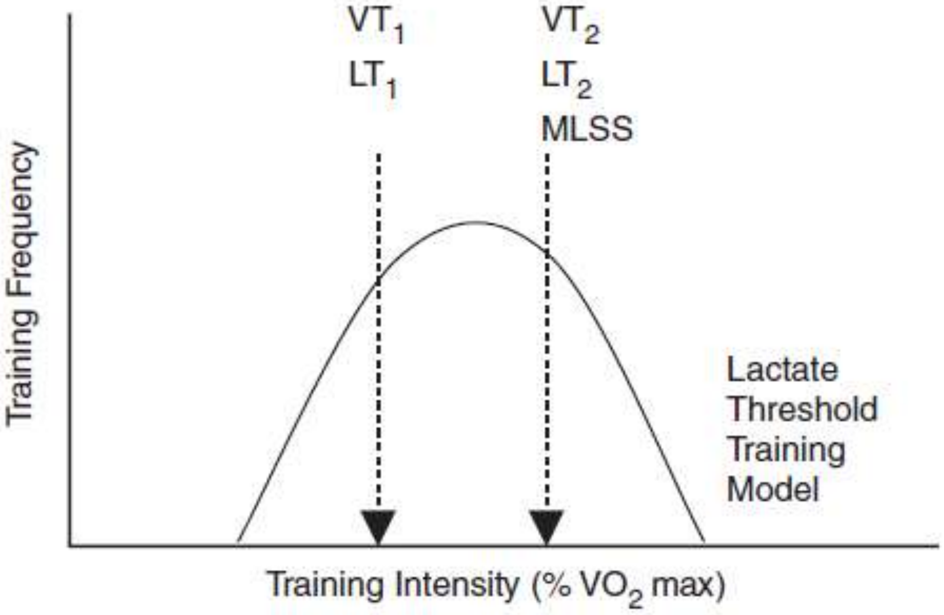
«This study supports and provides a historical context for data from elite endurance athletes suggesting that the optimal training organization for maximal performance is a ***polarized model of training*** *with about* ***75%*** *of training performed well below the lactate threshold and* ***15%–20%*** *well above that intensity.”*

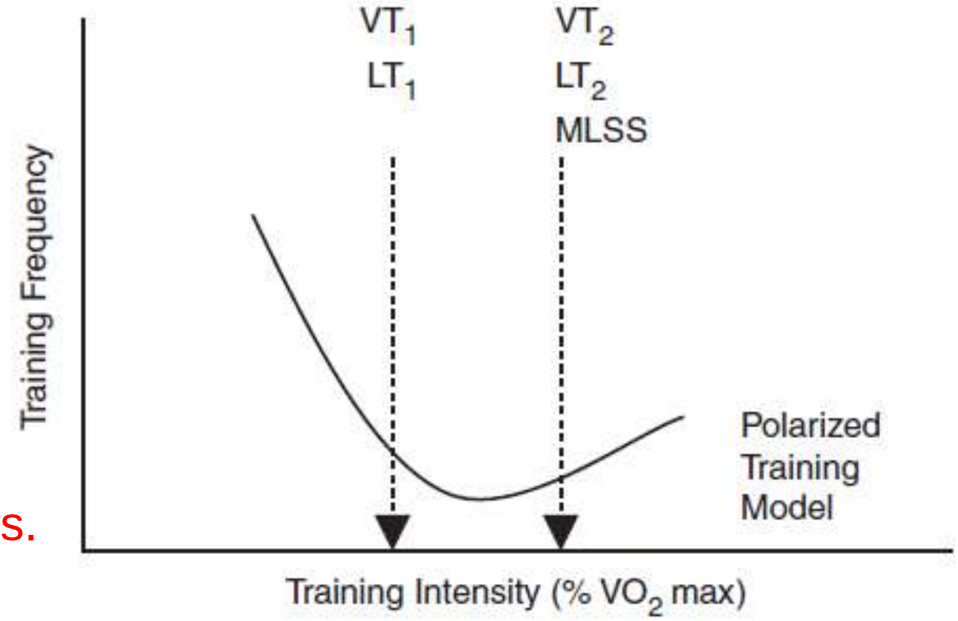
Fiskerstrand & Seiler, **Scand.J. Med Sci. Sports** 14:303-310, 2004

Seiler & Kjerland. Quantifying training distribution in elite endurance athletes: is there evidence of an optimal distribution? Scand. J. Med. Sci. Sports. 16, 49-56, 2006.

Glenn Kjerland



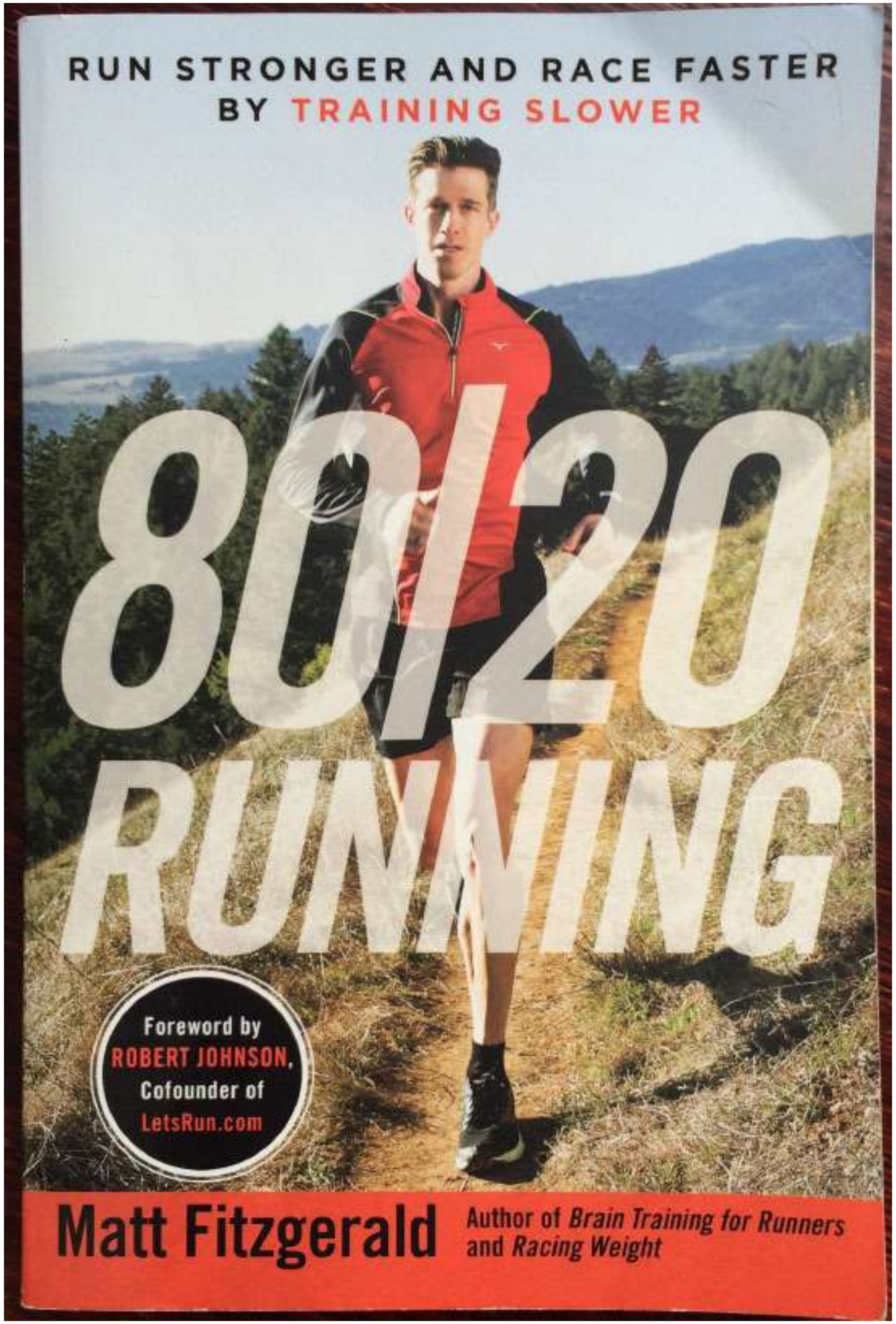

VT$_1$
LT$_1$
VT$_2$
LT$_2$
MLSS
Training Frequency
Lactate Threshold Training Model
Training Intensity (% VO$_2$ max)


VT$_1$
LT$_1$
VT$_2$
LT$_2$
MLSS
Training Frequency
Polarized Training Model
Training Intensity (% VO$_2$ max)

Scand. J. Med. Sci. Sports.
16, 49-56, 2006.

A big portion of the current evidence base

- What is best practice for training intensity and duration distribution in endurance athletes?
- Intervals, Thresholds, and Long Slow Distance: the Role of Intensity and Duration in Endurance Training
- From Heart-Rate Data to Training Quantification: A Comparison of 3 Methods of Training-Intensity Analysis
- The Road to Gold: Training and Peaking Characteristics in the Year Prior to a Gold Medal Endurance Performance
- Physical and Training Characteristics of top class marathoners
- Does Polarized Training Improve Performance in Recreational Runners?
- Quantifying training intensity distribution in elite endurance athletes: Is there evidence for an "optimal" distribution?
- Training and performance characteristics among Norwegian International Rowers 1970–2001
- The Annual Training Periodization of 8 World Champions in Orienteering
- Do Elite Endurance Athletes Report Their Training Accurately?
- Training-Intensity Distribution During an Ironman Season: Relationship With Competition Performance
- **Adaptations to aerobic interval training: Interactive effects of exercise intensity and total work duration**
- Autonomic recovery after exercise in trained athletes: intensity and duration effects
- **Polarized training has greater impact on key endurance variables than threshold, high intensity, or high volume training**
- **Six weeks of a polarized training-intensity distribution leads to greater physiological and performance adaptations than a threshold model in trained cyclists**
- **A Quasi-Experimental Study of Chinese Top-Level Speed Skaters’Training Load: Threshold Versus Polarized Model**
- Impact of training intensity distribution on performance in endurance athletes
- Lactate profile changes in relation to training characteristics in junior elite cyclists
- Training methods and intensity distribution of young world-class rowers


RUN STRONGER AND RACE FASTER
BY TRAINING SLOWER
80/20
RUNNING
Foreword by
ROBERT JOHNSON,
Cofounder of
LetsRun.com
Matt Fitzgerald
Author of Brain Training for Runners
and Racing Weight

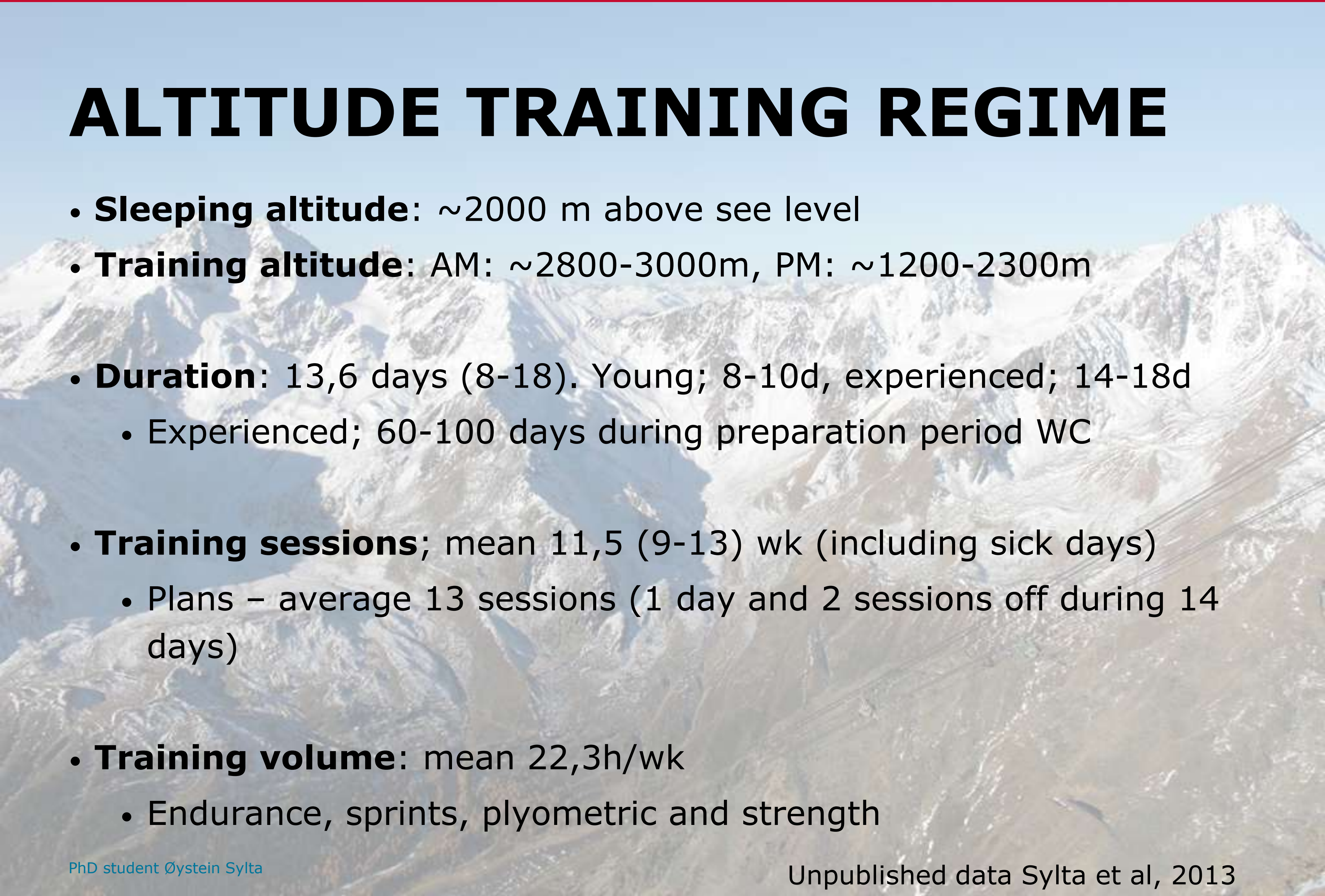
Some of the experts whose research was discussed

*Stephen Seiler- He wrote my name like 45 times (but who is counting)!
Jonathon Esteve-Lanao
Veronique Billat
Samuele Marcola
Thomas Stoggl & Billy Sperlich
Stuart Galloway
Rex Mauger & Nick Sculthorpe

«Do 80% of your running at low intensity, and the remaining 20% at moderate to high intensity. The rest is details»- Robert Johnson, founder of Letsrun.com

Some «details» beyond 80/20:

1. Does the intensity distribution change during altitude camp?



ALTITUDE TRAINING REGIME

- **Sleeping altitude**: ~2000 m above see level
- **Training altitude**: AM: ~2800-3000m, PM: ~1200-2300m

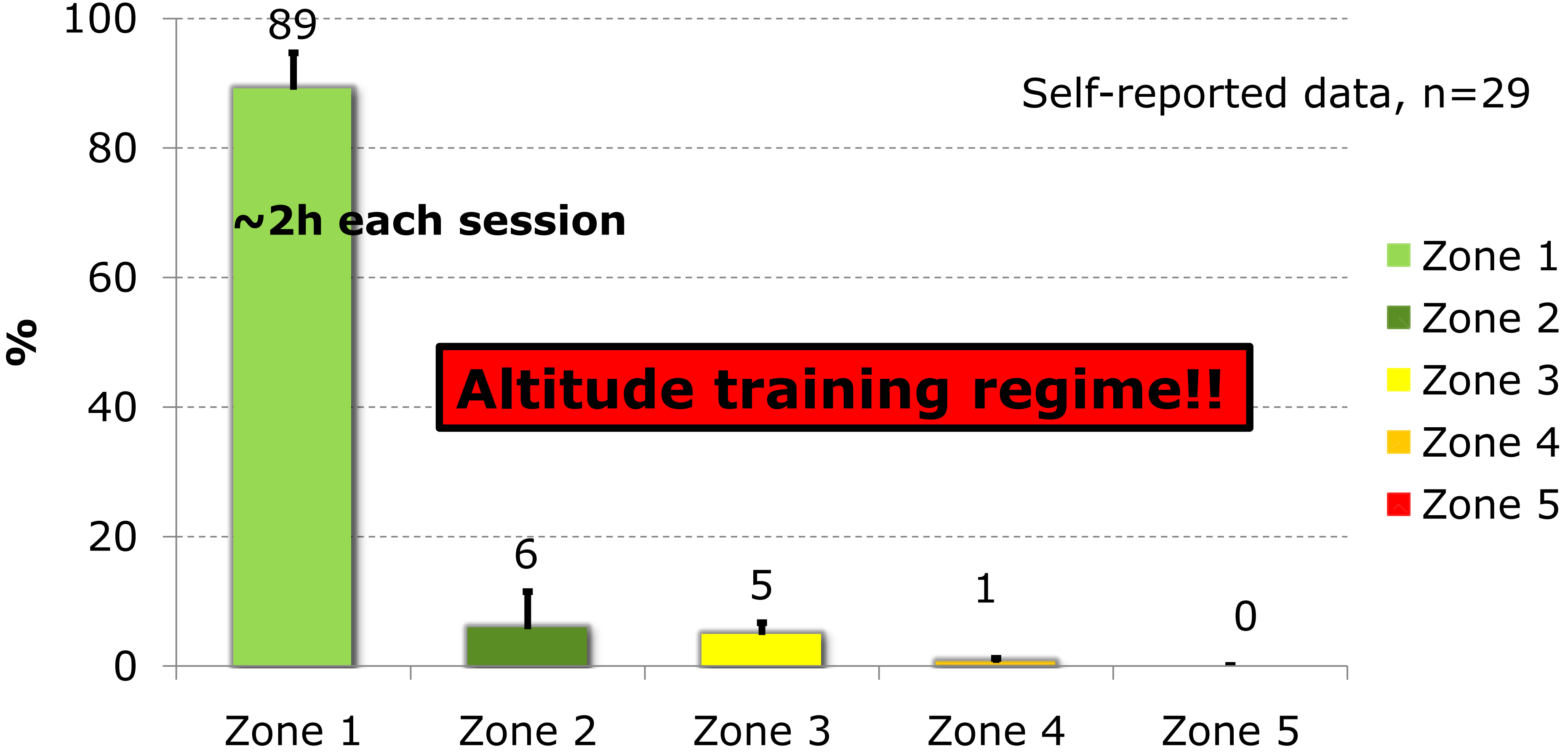
- **Duration**: 13,6 days (8-18). Young; 8-10d, experienced; 14-18d
  - Experienced; 60-100 days during preparation period WC

- **Training sessions**; mean 11,5 (9-13) wk (including sick days)
  - Plans – average 13 sessions (1 day and 2 sessions off during 14 days)

- **Training volume**: mean 22,3h/wk
  - Endurance, sprints, plyometric and strength

Unpublished data Sylta et al, 2013

INTENSITY DISTRIBUTION

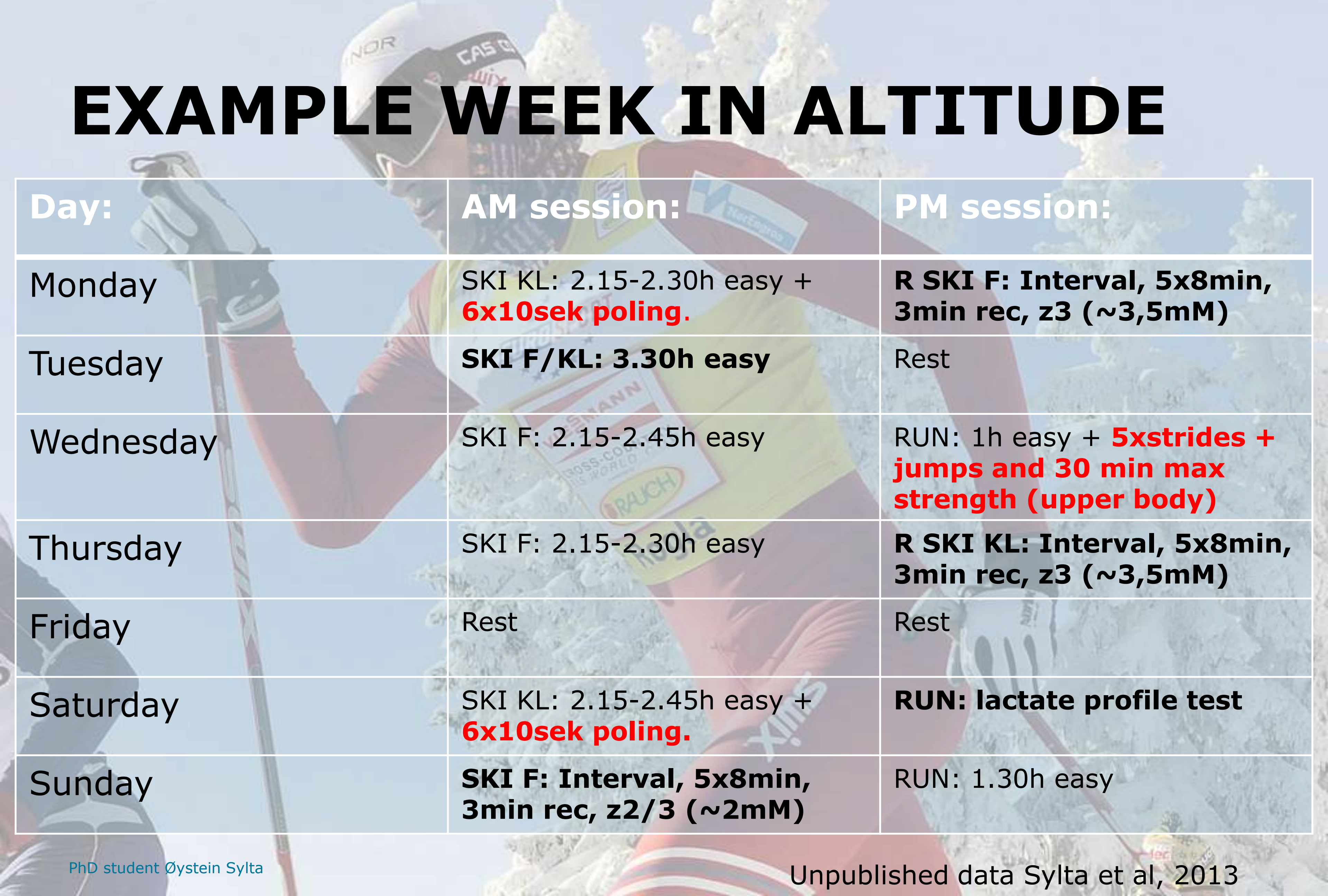


Self-reported data, n=29

~2h each session

Altitude training regime!!

Unpublished data Sylta et al, 2013

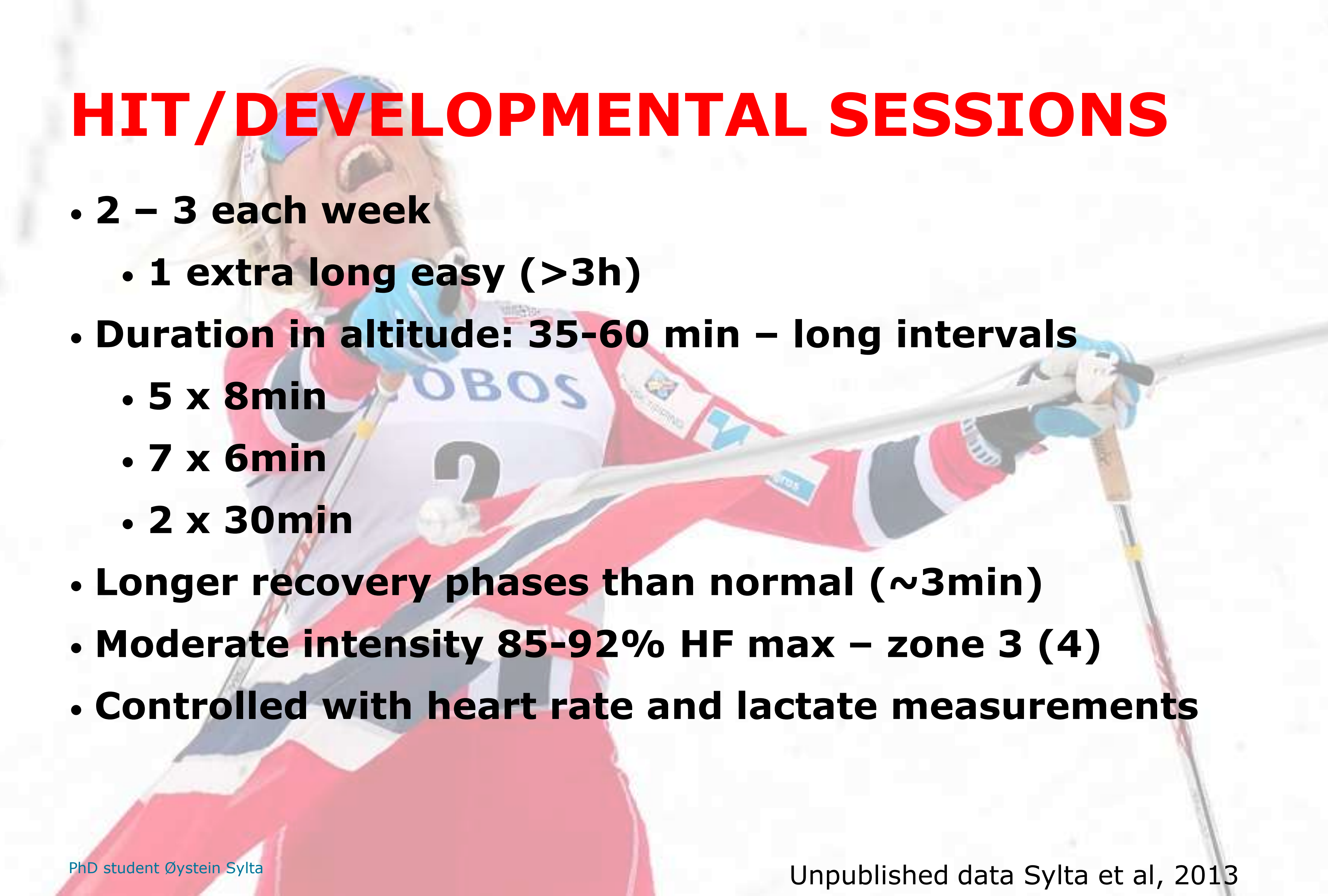


EXAMPLE WEEK IN ALTITUDE

Day:	**AM session:**	**PM session:**
Monday	SKI KL: 2.15-2.30h easy + **6x10sek poling**.	**R SKI F: Interval, 5x8min, 3min rec, z3 (~3,5mM)**
Tuesday	**SKI F/KL: 3.30h easy**	Rest
Wednesday	SKI F: 2.15-2.45h easy	RUN: 1h easy + **5xstrides + jumps and 30 min max strength (upper body)**
Thursday	SKI F: 2.15-2.30h easy	**R SKI KL: Interval, 5x8min, 3min rec, z3 (~3,5mM)**
Friday	Rest	Rest
Saturday	SKI KL: 2.15-2.45h easy + **6x10sek poling.**	**RUN: lactate profile test**
Sunday	**SKI F: Interval, 5x8min, 3min rec, z2/3 (~2mM)**	RUN: 1.30h easy

Unpublished data Sylta et al, 2013

HIT/DEVELOPMENTAL SESSIONS



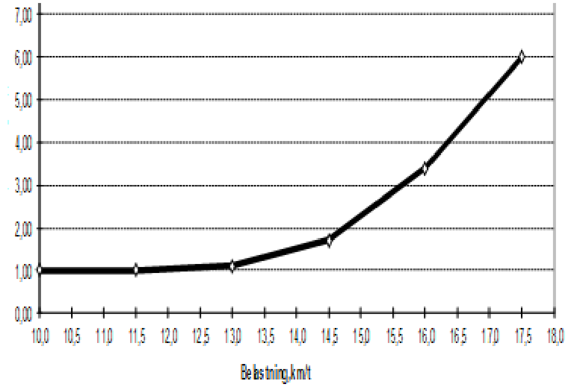
- 2 – 3 each week
    - 1 extra long easy (>3h)
- Duration in altitude: 35-60 min – long intervals
    - 5 x 8min
    - 7 x 6min
    - 2 x 30min
- Longer recovery phases than normal (~3min)
- Moderate intensity 85-92% HF max – zone 3 (4)
- Controlled with heart rate and lactate measurements

Unpublished data Sylta et al, 2013

Tight intensity control!

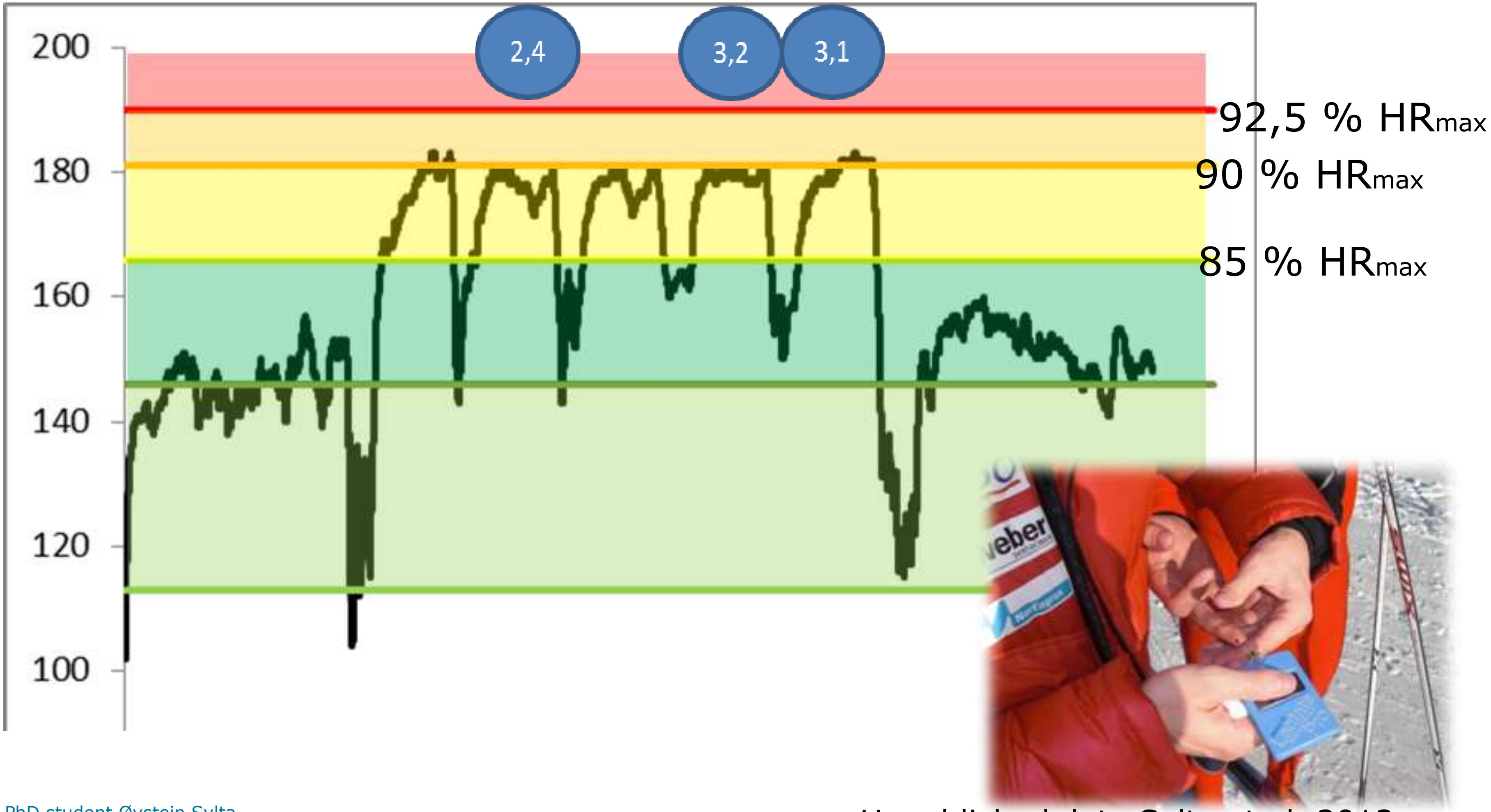
LACTATE PROFILE TESTS

	6,6	7,5	8,4	9,3	10,2	11,1
Val S.	-	125	137	145	152	
14.10.2011	0,5	0,6	0,8	0,9	1,1	
Val S.	120	133	142	149	157	
21.10.2011	0,4	0,6	0,6	0,8	1,1	
Val S.	119	128	131	137	149	
21.10.2012	0,6	0,6	0,6	0,5	0,8	
Val S.	117	127	134	146	152	
26.10.2012	0,5	0,6	0,8	1,0	1,3	

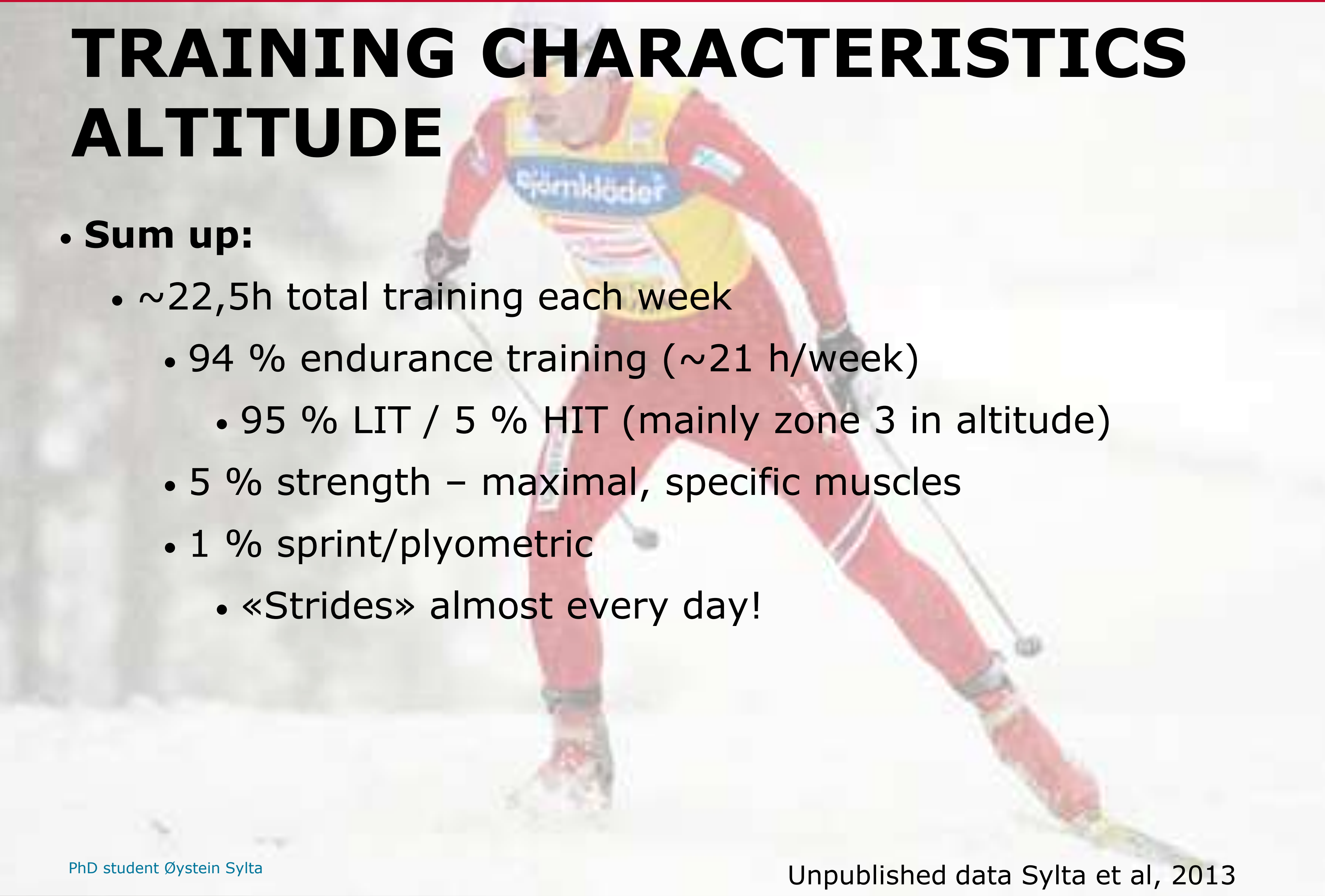


PhD student Øystein Sylta

Intervall session, 8x5min



Unpublished data Sylta et al, 2013



TRAINING CHARACTERISTICS ALTITUDE

- **Sum up:**
  - ~22,5h total training each week
    - 94 % endurance training (~21 h/week)
      - 95 % LIT / 5 % HIT (mainly zone 3 in altitude)
    - 5 % strength – maximal, specific muscles
    - 1 % sprint/plyometric
      - «Strides» almost every day!

Unpublished data Sylta et al, 2013

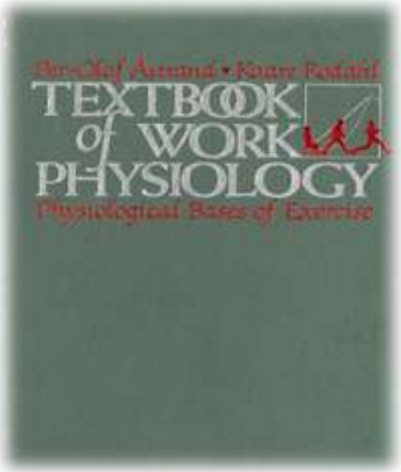
The «details» beyond 80/20:

2. HIIT training – How do work intensity and accumulated duration **interact** in regulating the adaptive signal?

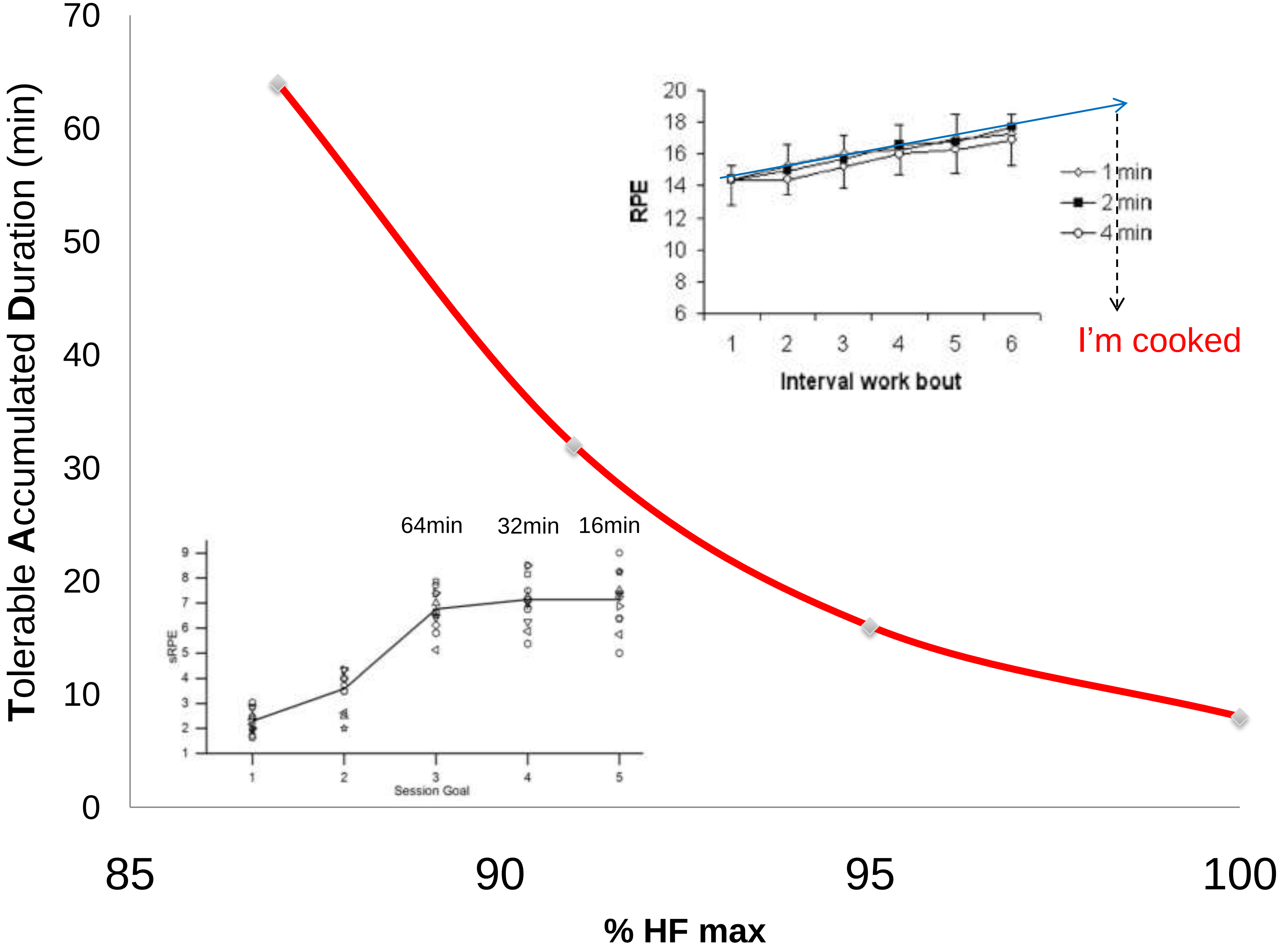
"It is an important but unsolved question which type of training is most effective: to maintain a level representing **90% of the maximal oxygen uptake for 40 min**, or to **tax 100% of the oxygen uptake capacity for 16 min**"

(Åstrand & Rodahl, Textbook of Work Physiology, 1970).

Per Åstrand in 1963



Per-Olof Åstrand • Kaare Rodahl
TEXTBOOK of WORK PHYSIOLOGY
Physiological Bases of Exercise



I’m cooked

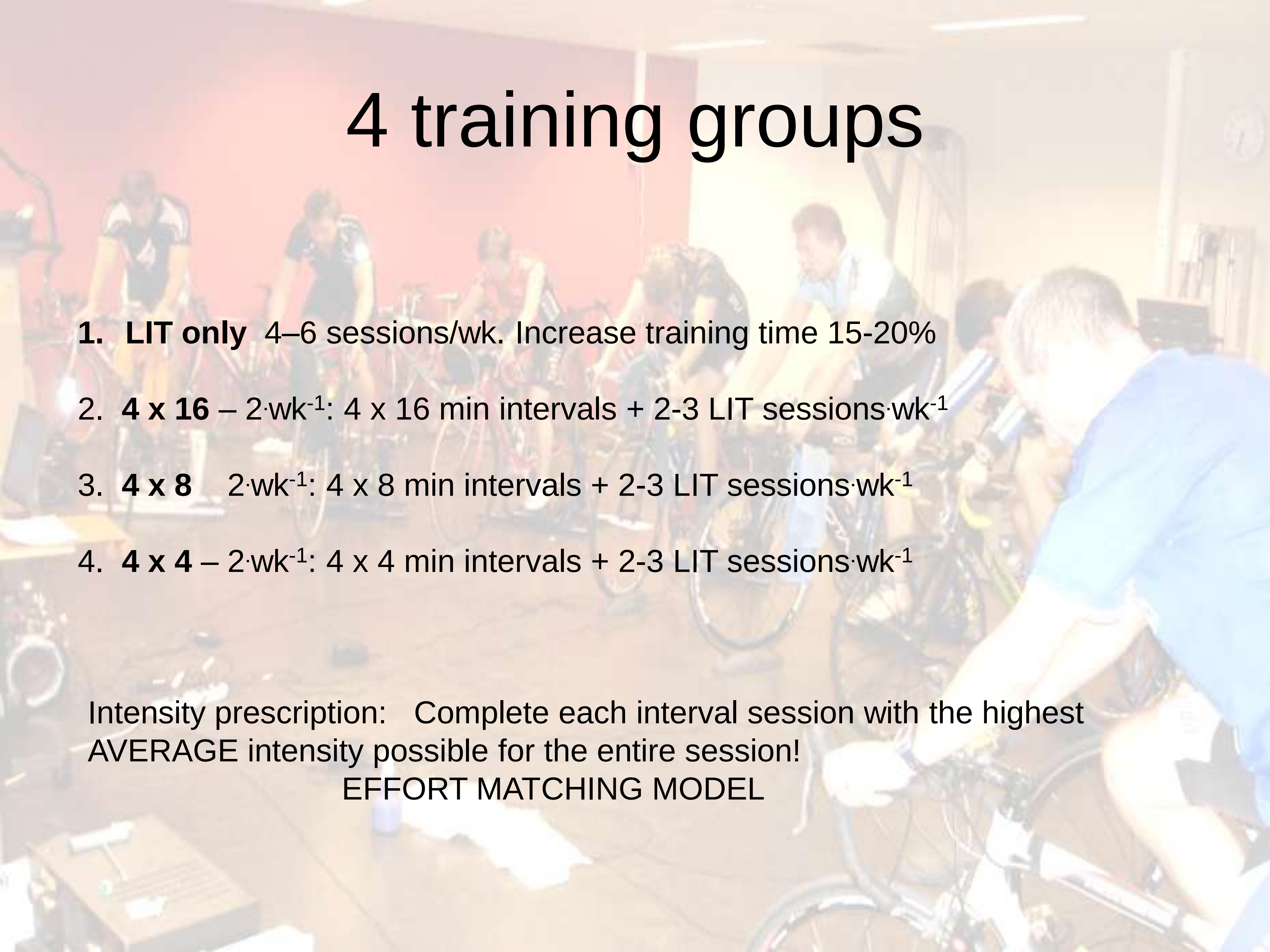
Tolerable Accumulated Duration (min)
0
10
20
30
40
50
60
70
85
90
95
100
% HF max
RPE
20
18
16
14
12
10
8
6
1
2
3
4
5
6
Interval work bout
1 min
2 min
4 min
64min
32min
16min
sRPE
1
2
3
4
5
6
7
8
9
1
2
3
4
5
Session Goal

Adaptations to aerobic interval training: interactive effects of exercise intensity and total work duration.

S Seiler, K Jøranson, B V Olesen, K J Hetlelid

Scand. J. Med. Sci. Sports 23:74-83, 2013

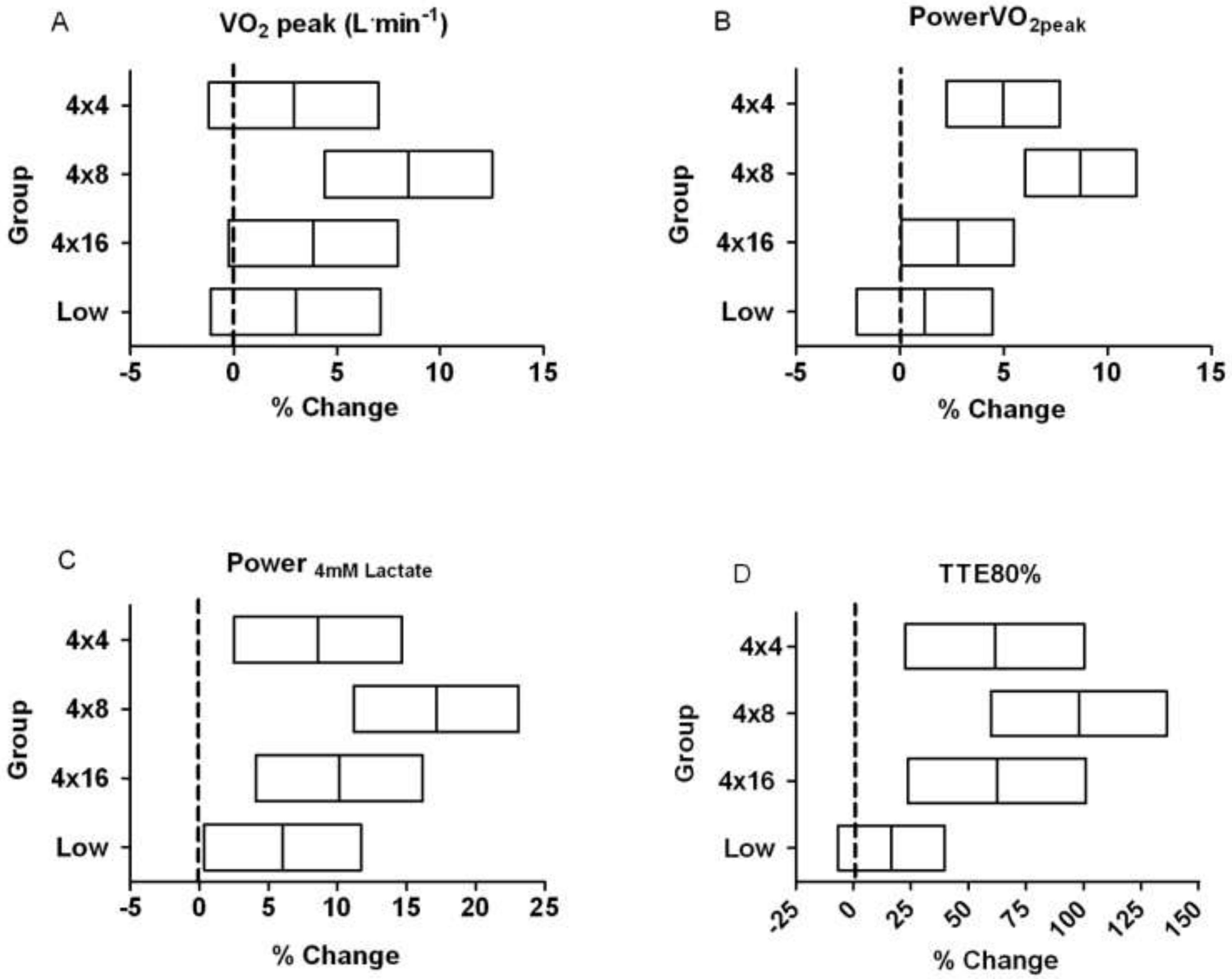
4 training groups

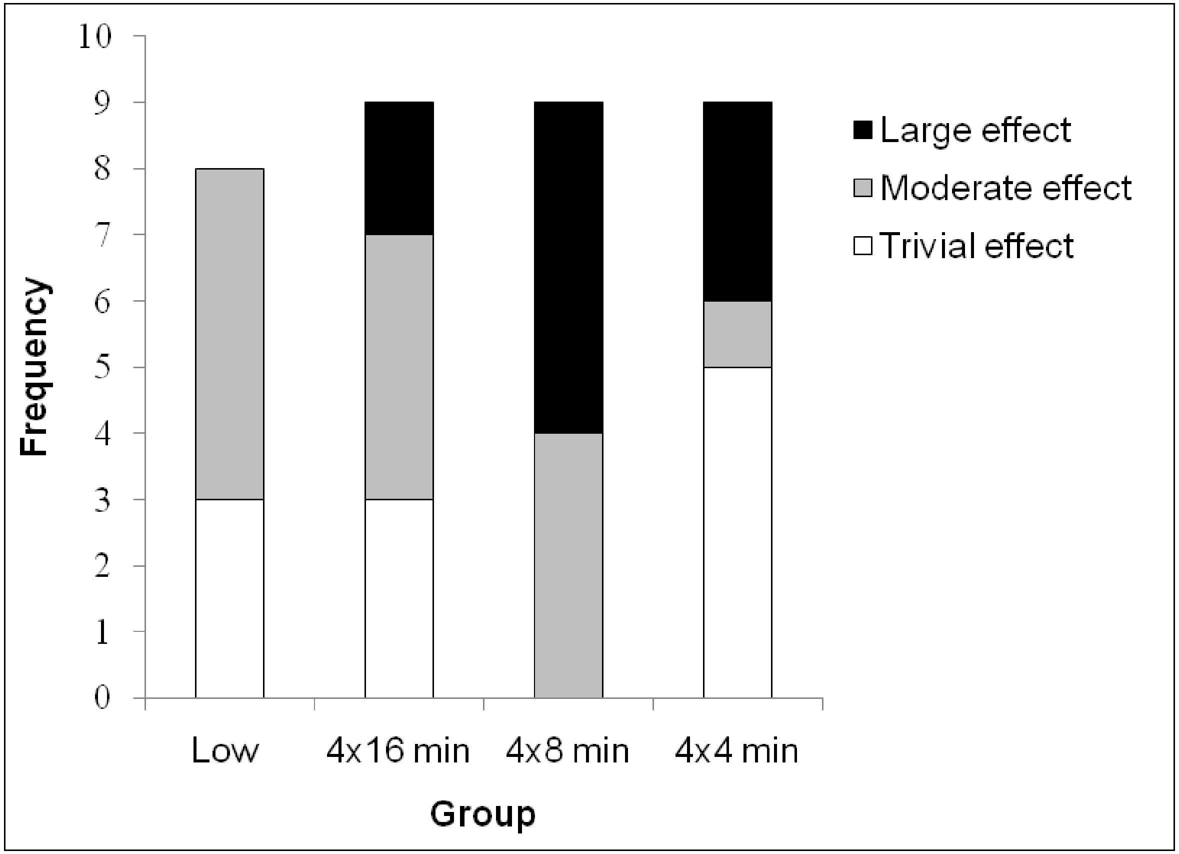


1. **LIT only** 4–6 sessions/wk. Increase training time 15-20%
2. **4 x 16** – $2 \cdot \mathrm{wk}^{-1}$: 4 x 16 min intervals + 2-3 LIT $\mathrm{sessions} \cdot \mathrm{wk}^{-1}$
3. **4 x 8** $2 \cdot \mathrm{wk}^{-1}$: 4 x 8 min intervals + 2-3 LIT $\mathrm{sessions} \cdot \mathrm{wk}^{-1}$
4. **4 x 4** – $2 \cdot \mathrm{wk}^{-1}$: 4 x 4 min intervals + 2-3 LIT $\mathrm{sessions} \cdot \mathrm{wk}^{-1}$

Intensity prescription: Complete each interval session with the highest AVERAGE intensity possible for the entire session!

EFFORT MATCHING MODEL


A
VO2 peak (L·min-1)
Group
4x4
4x8
4x16
Low
-5
0
5
10
15
% Change
B
PowerVO2peak
Group
4x4
4x8
4x16
Low
-5
0
5
10
15
% Change
C
Power 4mM Lactate
Group
4x4
4x8
4x16
Low
-5
0
5
10
15
20
25
% Change
D
TTE80%
Group
4x4
4x8
4x16
Low
-25
0
25
50
75
100
125
150
% Change



Seiler S, Jøranson K, Olesen BV, Hetlelid KJ. Adaptations To Aerobic Interval Training: Interactive Effects Of Exercise Intensity And Total Work Duration. Scand. J. Med Sci Sports 23, 74-83, 2013.

Distribution of individual response to training by group-averaged change in VO_2peak (l/min), power at VO_2peak (W), and Power at 4mM blood lactate concentration (W).

Averaged response for each subject was categorized as negative to trivial: <4% improvement, moderate: 4–9% improvement, or large:>9% improvement. The distribution of individual responses was significantly different among the four groups ($P<0.05$).

Effects of intensity and duration in aerobic high intensity interval training in highly trained junior cross country skiers

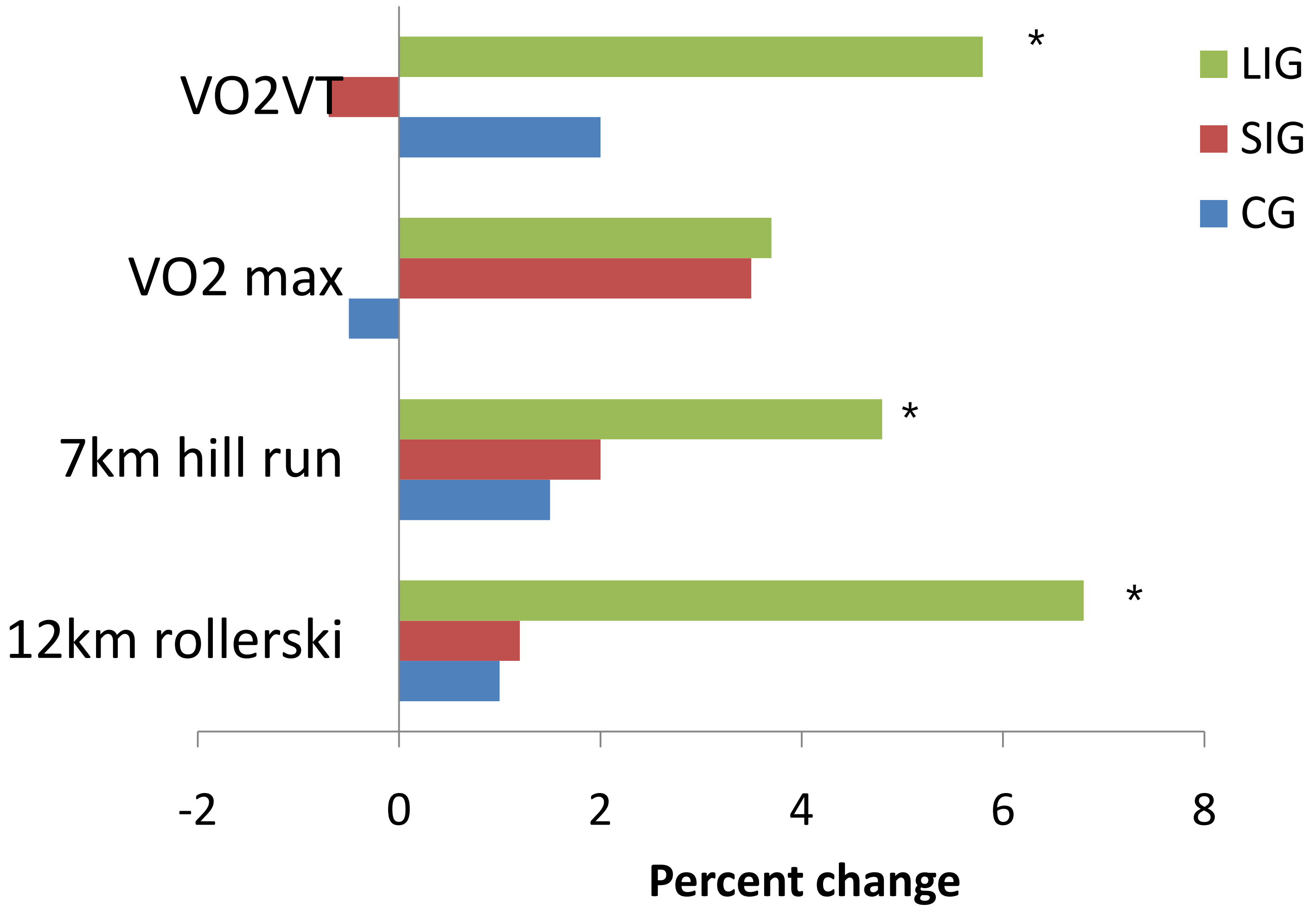
Sandbakk, Ø. et al.

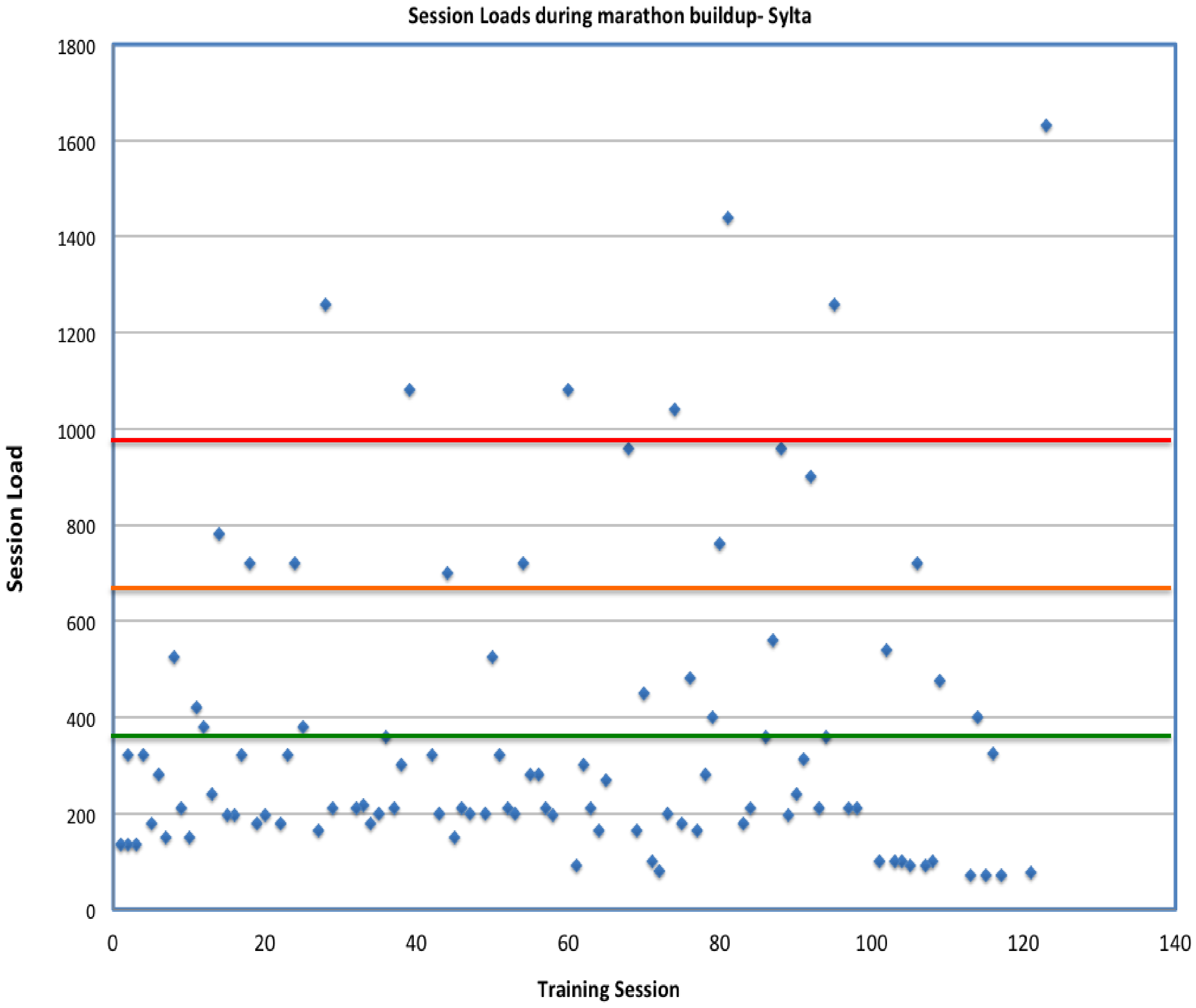
J Strength and Cond. Res.
27(7):1974-80. 2013

Øyvind Sandbakk

Methods

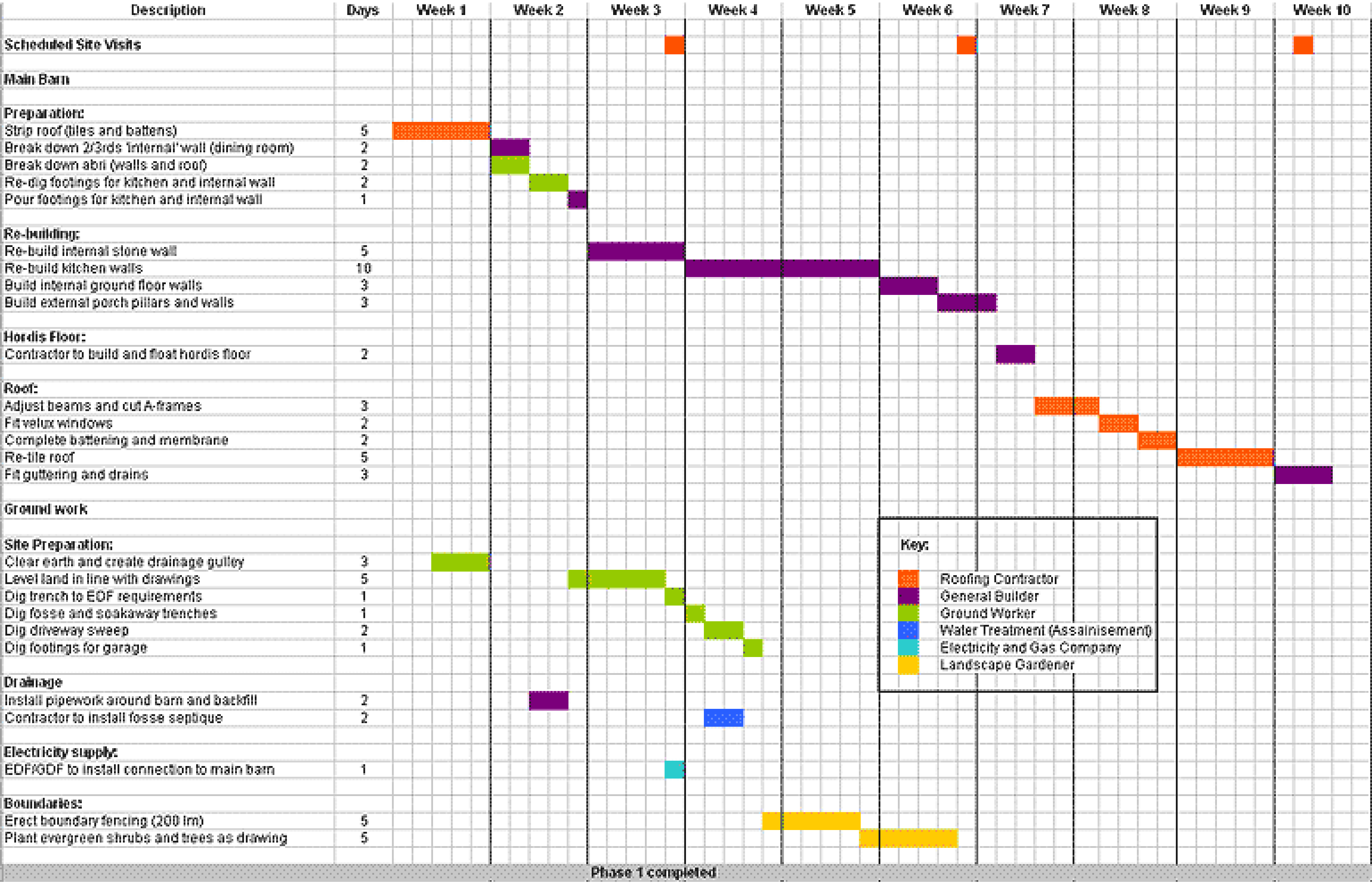
- Well trained junior XC skiers
- N= 20- 8 weeks high volume, low intensity
- Then divided into a long interval group (LIG) and a short interval group (SIG) plus a control group (CG) for
- *CG= 2 additional low intensity sessions/wk*
- *SIG= 2 interval sessions/wk 94% HR max (**2-4min**), (15-20 min total work),* ***RPE 18***
- *LIG = 2 interval sessions/wk 91% HR max (**5-10 min**), (40-45 min total work),* ***RPE 18***


VO2VT
VO2 max
7km hill run
12km rollerski
*
*
*
LIG
SIG
CG
-2
0
2
4
6
8
Percent change


Session Loads during marathon buildup- Sylta
Session Load
Training Session
0
200
400
600
800
1000
1200
1400
1600
1800
0
20
40
60
80
100
120
140

Moving beyond 80/20:

3. Does Periodization matter?

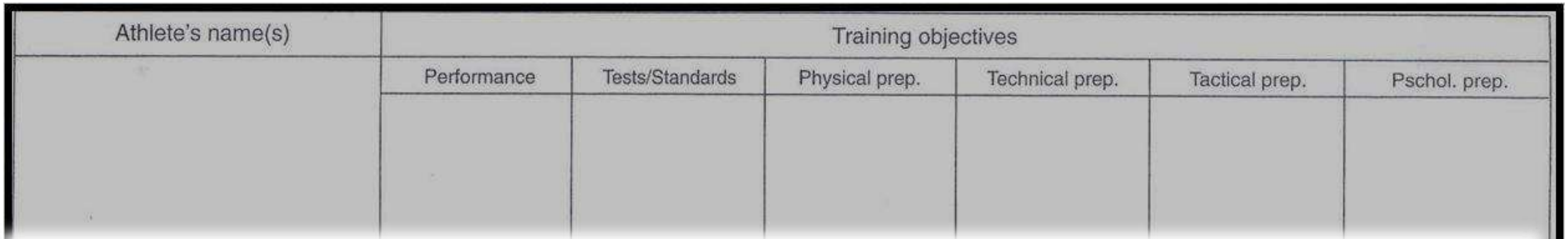


Description	Days	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Scheduled Site Visits				····🟧			····🟧				·🟧···
Main Barn											
Preparation:											
Strip roof (tiles and battens)	5	🟧🟧🟧🟧🟧									
Break down 2/3rds 'internal' wall (dining room)	2		🟪🟪···								
Break down abri (walls and roof)	2		🟩🟩···								
Re-dig footings for kitchen and internal wall	2		··🟩🟩·								
Pour footings for kitchen and internal wall	1		····🟪								
Re-building:											
Re-build internal stone wall	5			🟪🟪🟪🟪🟪							
Re-build kitchen walls	10				🟪🟪🟪🟪🟪	🟪🟪🟪🟪🟪					
Build internal ground floor walls	3						🟪🟪🟪··				
Build external porch pillars and walls	3						···🟪🟪	🟪····			
Hordis Floor:											
Contractor to build and float hordis floor	2							·🟪🟪··			
Roof:											
Adjust beams and cut A-frames	3							···🟧🟧	🟧····		
Fit velux windows	2								·🟧🟧··		
Complete battening and membrane	2								···🟧🟧		
Re-tile roof	5									🟧🟧🟧🟧🟧	
Fit guttering and drains	3										🟪🟪🟪··
Ground work											
Site Preparation:											
Clear earth and create drainage gulley	3	··🟩🟩🟩									
Level land in line with drawings	5		····🟩	🟩🟩🟩🟩·							
Dig trench to EDF requirements	1			····🟩							
Dig fosse and soakaway trenches	1				🟩····						
Dig driveway sweep	2				·🟩🟩··						
Dig footings for garage	1				···🟩·						
Drainage											
Install pipework around barn and backfill	2		··🟪🟪·								
Contractor to install fosse septique	2				·🟦🟦··						
Electricity supply:											
EDF/GDF to install connection to main barn	1			····▨							
Boundaries:											
Erect boundary fencing (200 lm)	5				····🟨	🟨🟨🟨🟨·					
Plant evergreen shrubs and trees as drawing	5					····🟨	🟨🟨🟨🟨·				

Key:

🟧	Roofing Contractor
🟪	General Builder
🟩	Ground Worker
🟦	Water Treatment (Assainisement)
▨	Electricity and Gas Company
🟨	Landscape Gardener

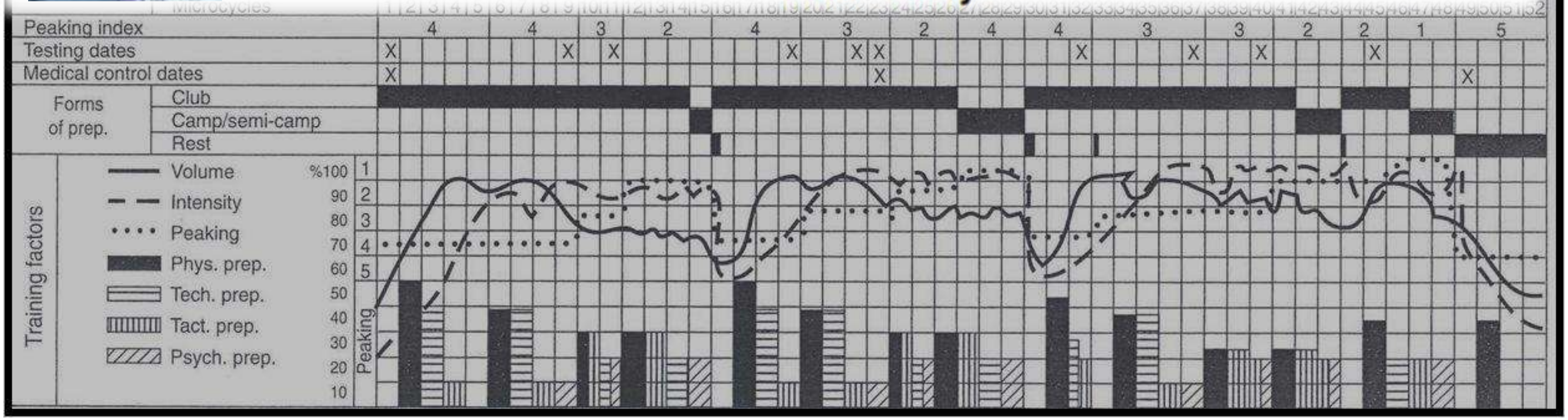
Phase 1 completed


Athlete's name(s)
Training objectives
Performance
Tests/Standards
Physical prep.
Technical prep.
Tactical prep.
Pschol. prep.

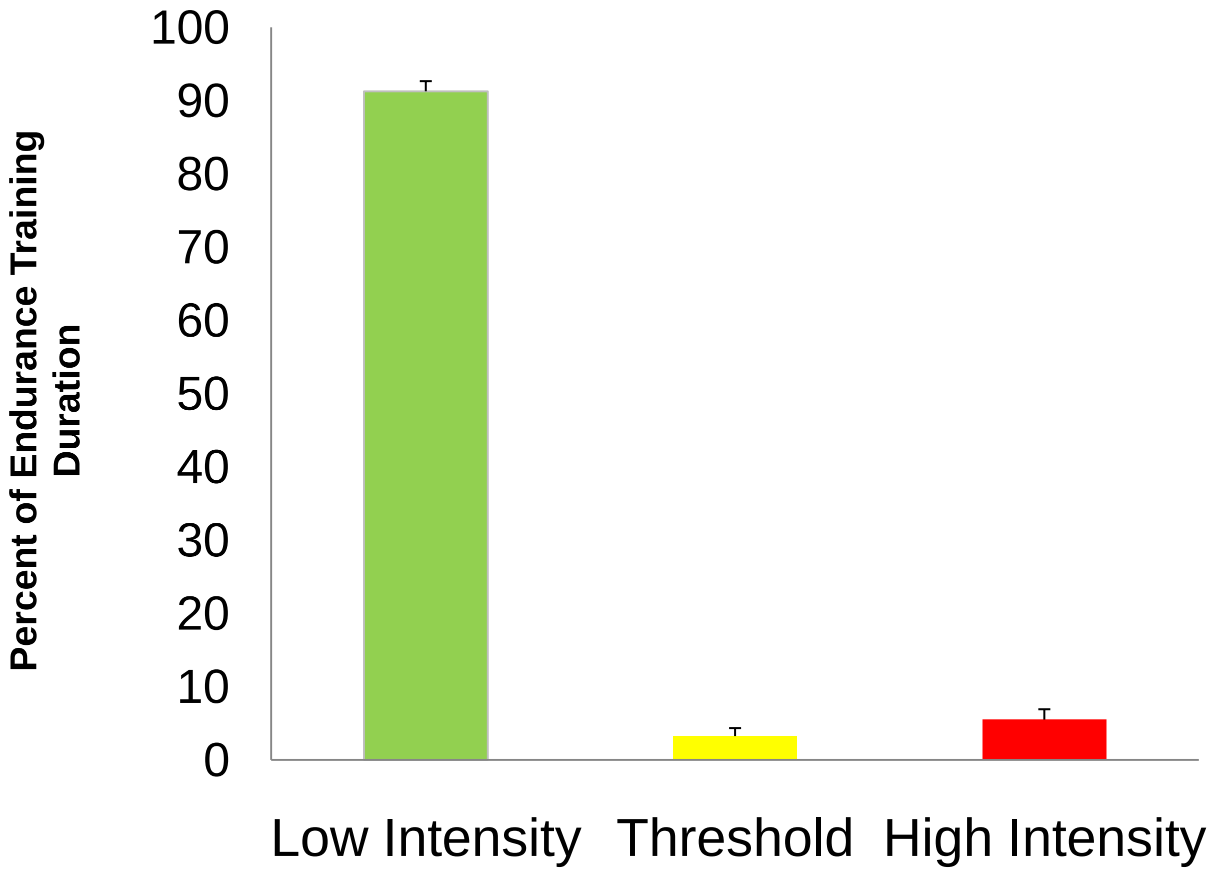
International Journal of Sports Physiology and Performance, 2012, 7, 242-250
© 2012 Human Kinetics, Inc.

Periodization Paradigms in the 21st Century: Evidence-Led or Tradition-Driven?

John Kiely

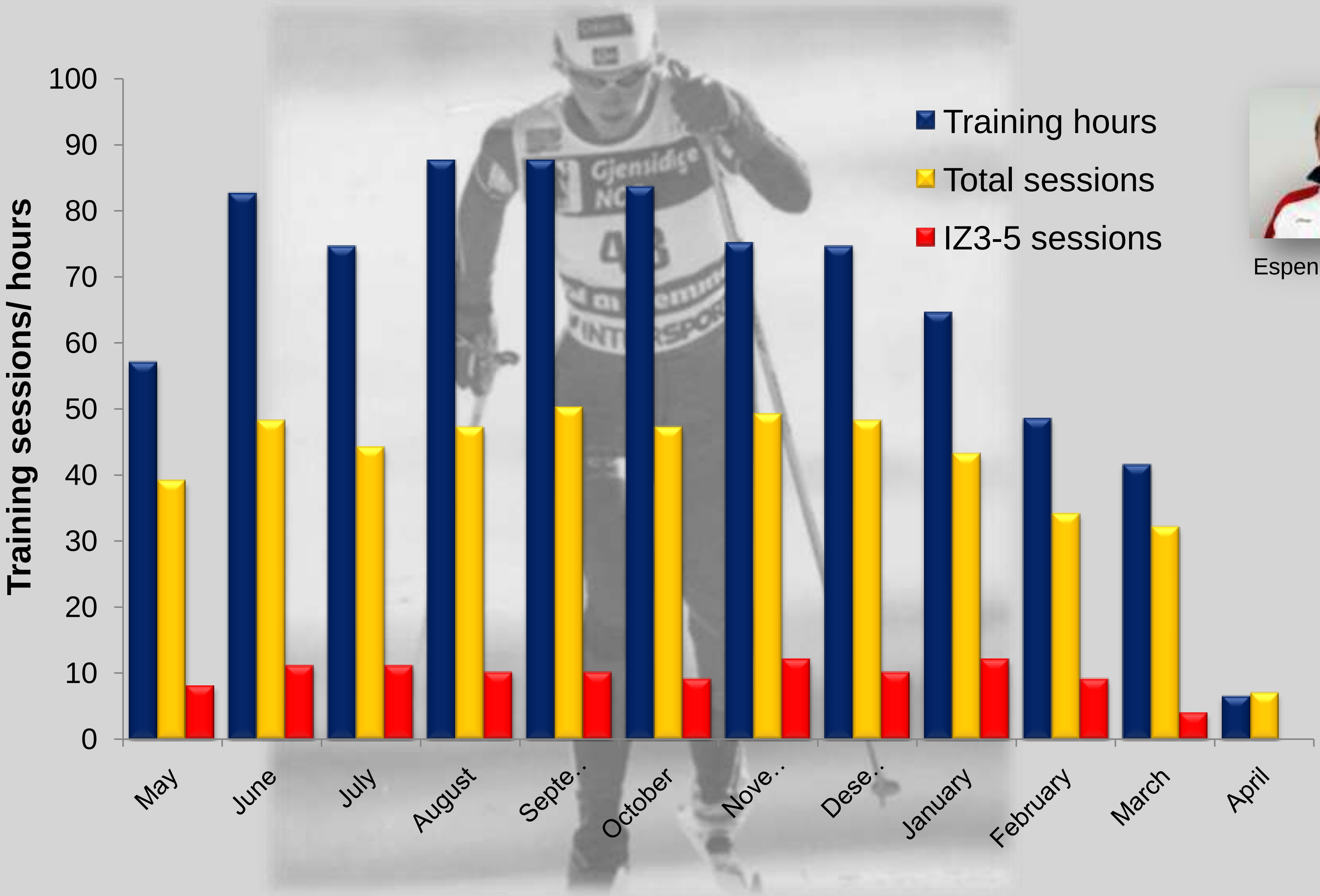


Annual intensity distribution of 12 Olympic/ World champions- XC skiing



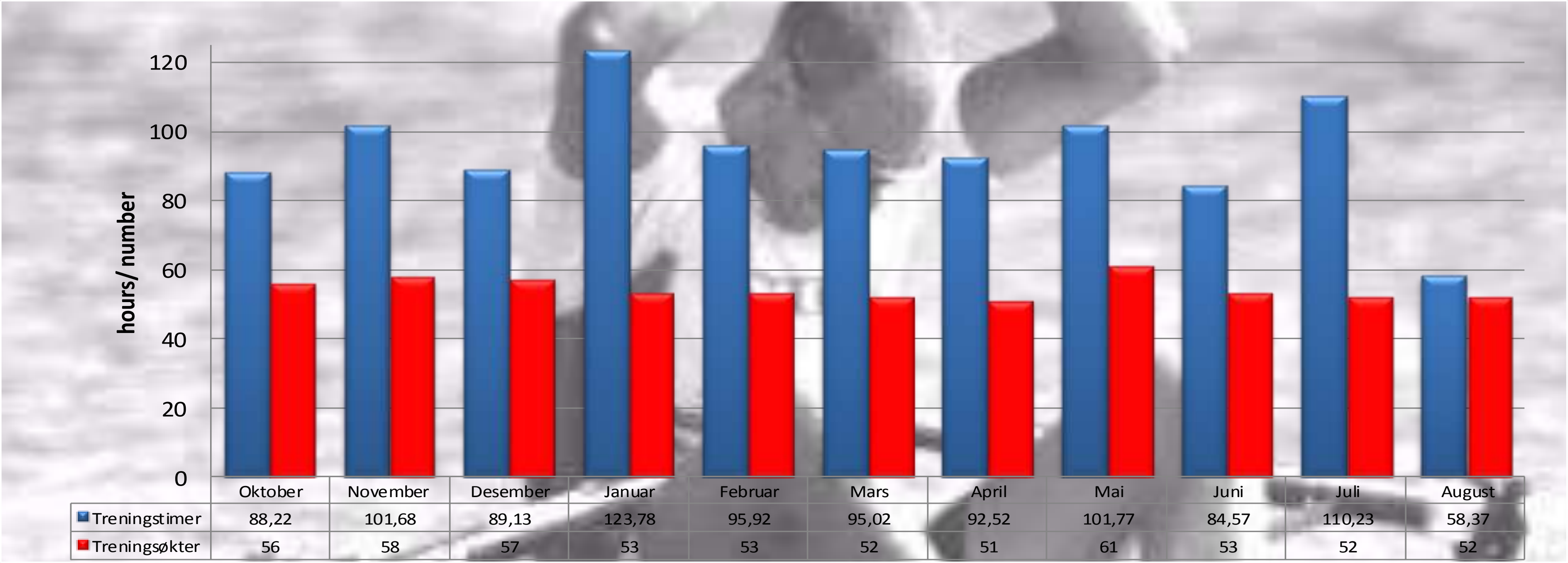
Espen Tønnessen, Øystein Sylta,Thomas A. Haugen, Erlend Hem, Ida S. Svendsen, Stephen Seiler
The Road to Gold: Training and Peaking Characteristics in the Year Prior to a Gold Medal Endurance Performance. PLOS One July 14, 2014 DOI: 10.1371/journal.pone.0101796

Basic periodization of a champion XC skier



Espen Tønnessen

Basic training periodization of a 2-time gold medal winning rower

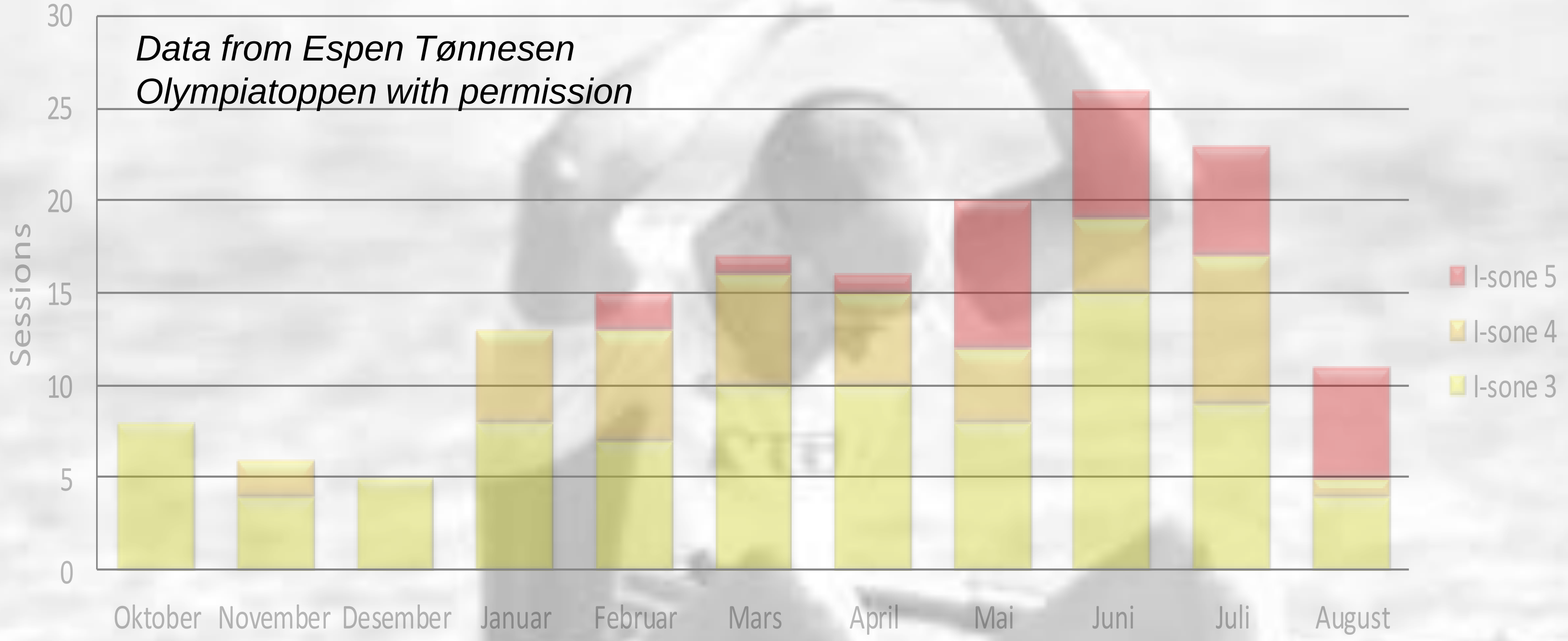


	Oktober	November	Desember	Januar	Februar	Mars	April	Mai	Juni	Juli	August
🟦 Treningstimer	88,22	101,68	89,13	123,78	95,92	95,02	92,52	101,77	84,57	110,23	58,37
🟥 Treningsøkter	56	58	57	53	53	52	51	61	53	52	52

Annual Total (gold medal year)

Total training hours:	1041
Total training sessions:	598
Rowing kilometers:	4911
Average hours per week:	21.7
Average # sessions per week	12.5

High intensity training sessions- champion rower



Data from Espen Tønnesen
Olympiatoppen with permission

Typical effective training time per session:

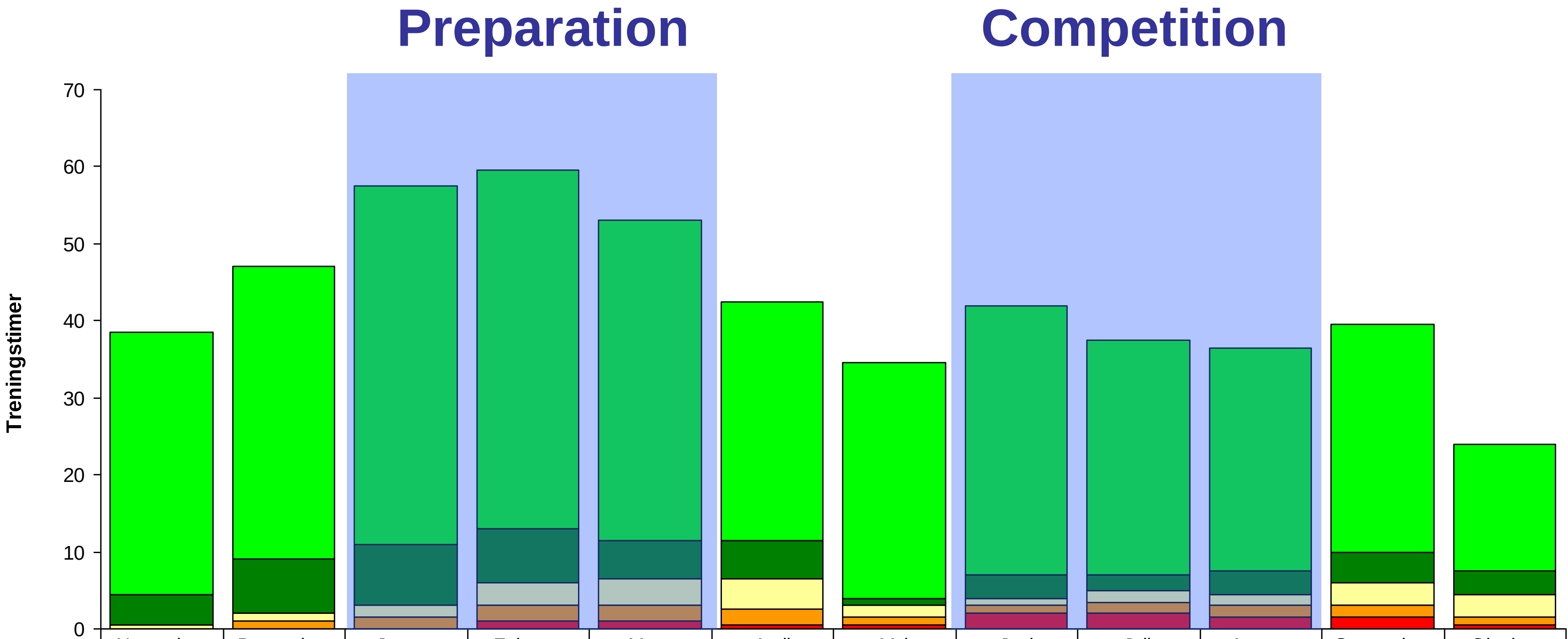
Zone 3: 60 min (e.g. 3 x 20 min, 5 min rec)

Zone 4: 60 min (6 x 10 min, 5 min rec)

Zone 5: 20 min (e.g 4 x 4 min, 3 min rec)

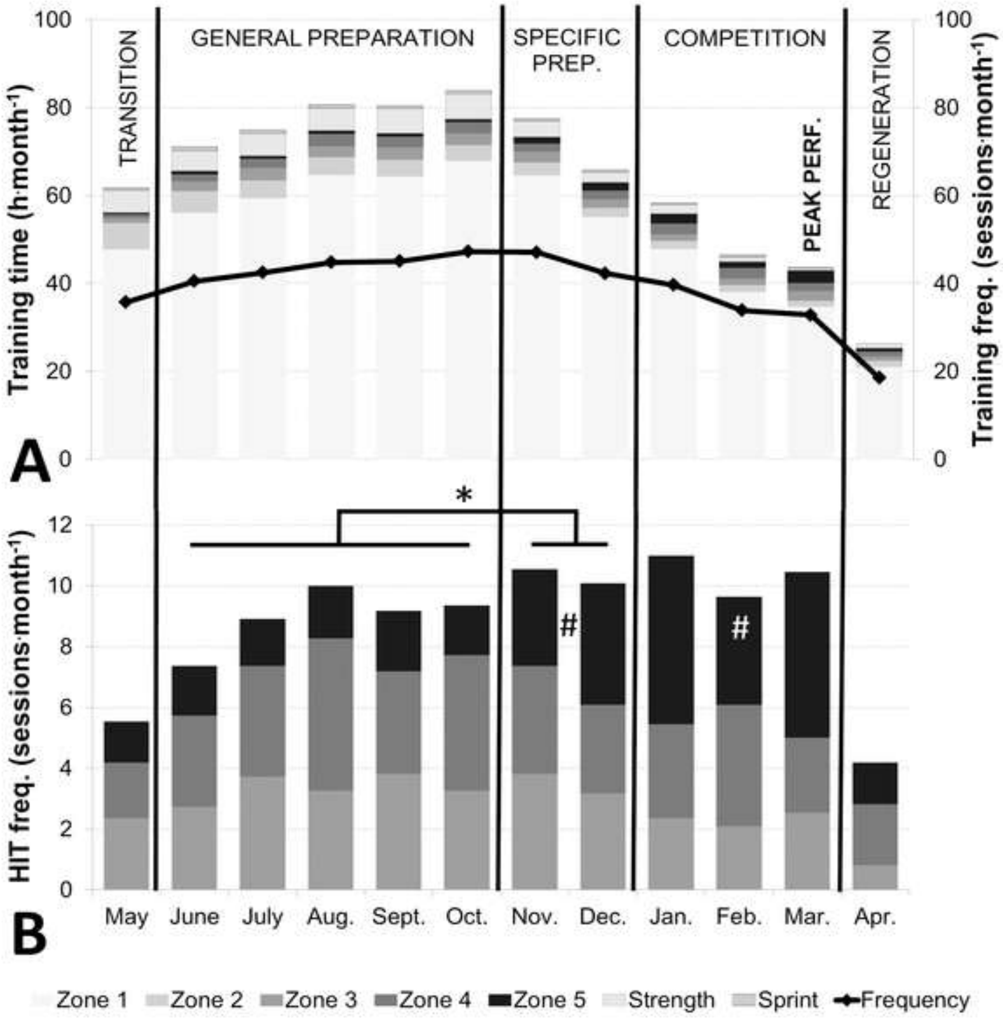
Ingrid Kristiansen
5 World Records
World Champion

Data from Espen Tønnesen
Olympiatoppen with permission



	November	Desember	Januar	Februar	Mars	April	Mai	Juni	Juli	August	September	Oktober
🟩 I-sone 1	34,00	38,00	46,50	46,50	41,50	31,00	30,50	35,00	30,50	29,00	29,50	16,50
🟩 I-sone 2	4,00	7,00	8,00	7,00	5,00	5,00	1,00	3,00	2,00	3,00	4,00	3,00
🟨 I-sone 3	0,50	1,00	1,50	3,00	3,50	4,00	1,50	1,00	1,50	1,50	3,00	3,00
🟧 I-sone 4		1,00	1,50	2,00	2,00	2,00	1,00	1,00	1,50	1,50	1,50	1,00
🟥 I-sone 5				1,00	1,00	0,50	0,50	2,00	2,00	1,50	1,50	0,50

Annual training characteristics of 12 champion XC skiers



Overall intensity distribution maintained through season

Frequency of hard sessions stable, but shift in intensity of HIT sessions towards more z5

Tønnessen E, Sylta Ø, Haugen TA, Hem E, Svendsen IS, Seiler S (2014) The Road to Gold: Training and Peaking Characteristics in the Year Prior to a Gold Medal Endurance Performance. PLoS ONE 9(7): e101796. doi:10.1371/journal.pone.0101796
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0101796

METHODS

Preparation period, 4wk

Pre testing

N = 69

Stratified randomization (VO_{2max}, experience, age)

Baseline characteristics in all training groups (N=63). Values are mean (SD).

	All (N=63)	**Traditional (N=23)**	**Hybrid (N=20)**	**Reversed (N=20)**
Age (years)	37.7 (7.8)	37.3 (9.3)	38.2 (6.8)	37.7 (7.2)
Body weight (kg)	79.9 (7.9)	80.3 (7.4)	79.7 (8.9)	79.7 (7.8)
Cycling experience (years)	5.5 (4.2)	5.8 (4.5)	6.3 (4.1)	4.4 (3.8)
Training volume last year (h·wk^{-1})	9.7 (3.3)	9.9 (3.5)	9.3 (3.1)	9.7 (3.4)
Power@40min TT (w·kg^{-1})	3.6 (0.4)	3.5 (0.4)	3.6 (0.4)	3.6 (0.5)
Power@4mM (w·kg^{-1})	3.6 (0.5)	3.5 (0.4)	3.6 (0.3)	3.6 (0.6)
PPO (w·kg^{-1})	5.3 (0.6)	5.2 (0.5)	5.4 (0.7)	5.2 (0.7)
$VO_{2\ PEAK}$ (ml·kg^{-1}·min^{-1})	61.3 (5.8)	61.9 (5.8)	61.3 (6.0)	60.5 (5.7)
$VO_{2\ PEAK}$ (L·min^{-1})	4.9 (0.5)	4.9 (0.5)	4.9 (0.5)	4.8 (0.4)

There were no significant differences among groups. One-way between-groups ANOVA analysis.

Preparation period, 4wk

Pre testing

N = 69

Stratified randomization (VO_{2max}, experience, age)

Intervention period, 12 weeks

Periodization model	Mesocycle 1 4 weeks	Mesocycle 2 4 weeks	Mesocycle 3 4 weeks
«Traditional model»	Zone 3	Zone 4	Zone 5
«Hybrid model»	Zone 3/4/5	Zone 3/4/5	Zone 3/4/5
«Reversed model»	Zone 5	Zone 4	Zone 3

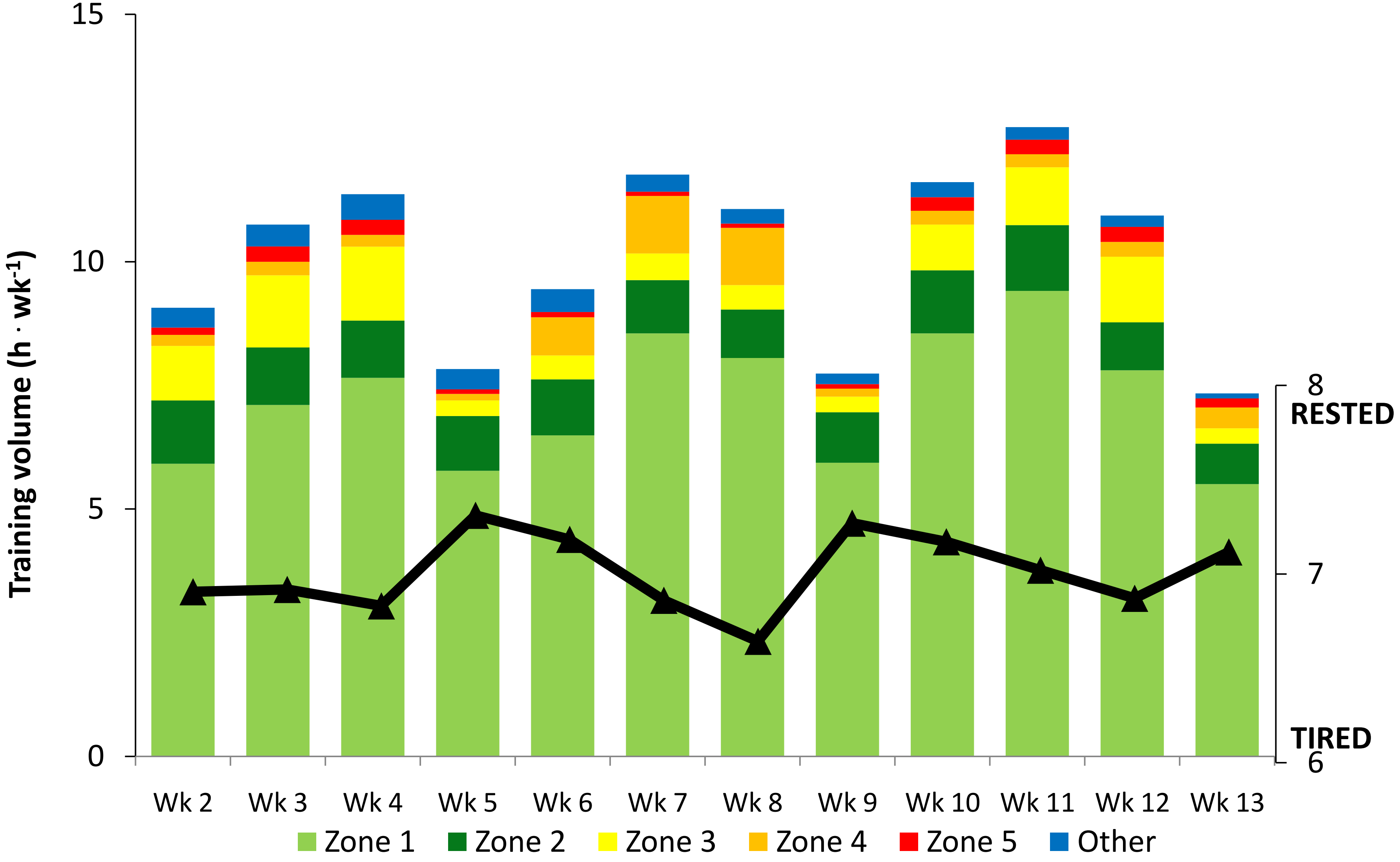
Post testing

6 subjects excluded from analysis due to illness, compliance or missing post test.

Interval sessions

Zone	Session	Intensity control
Zone 3	4 x 16min, 2min rest	All HIT sessions were recommended to be executed as «all out», BUT: 1 - Within the session structure (eg. only 2min rest) 2 – With even or progressive power, without failure 3 – Be able to complete all 24 HIT sessions in this prescribed way
Zone 4	4 x 8min, 2min rest	
Zone 5	4 x 4min, 2min rest	

Volume and intensity periodization - ALL GROUPS



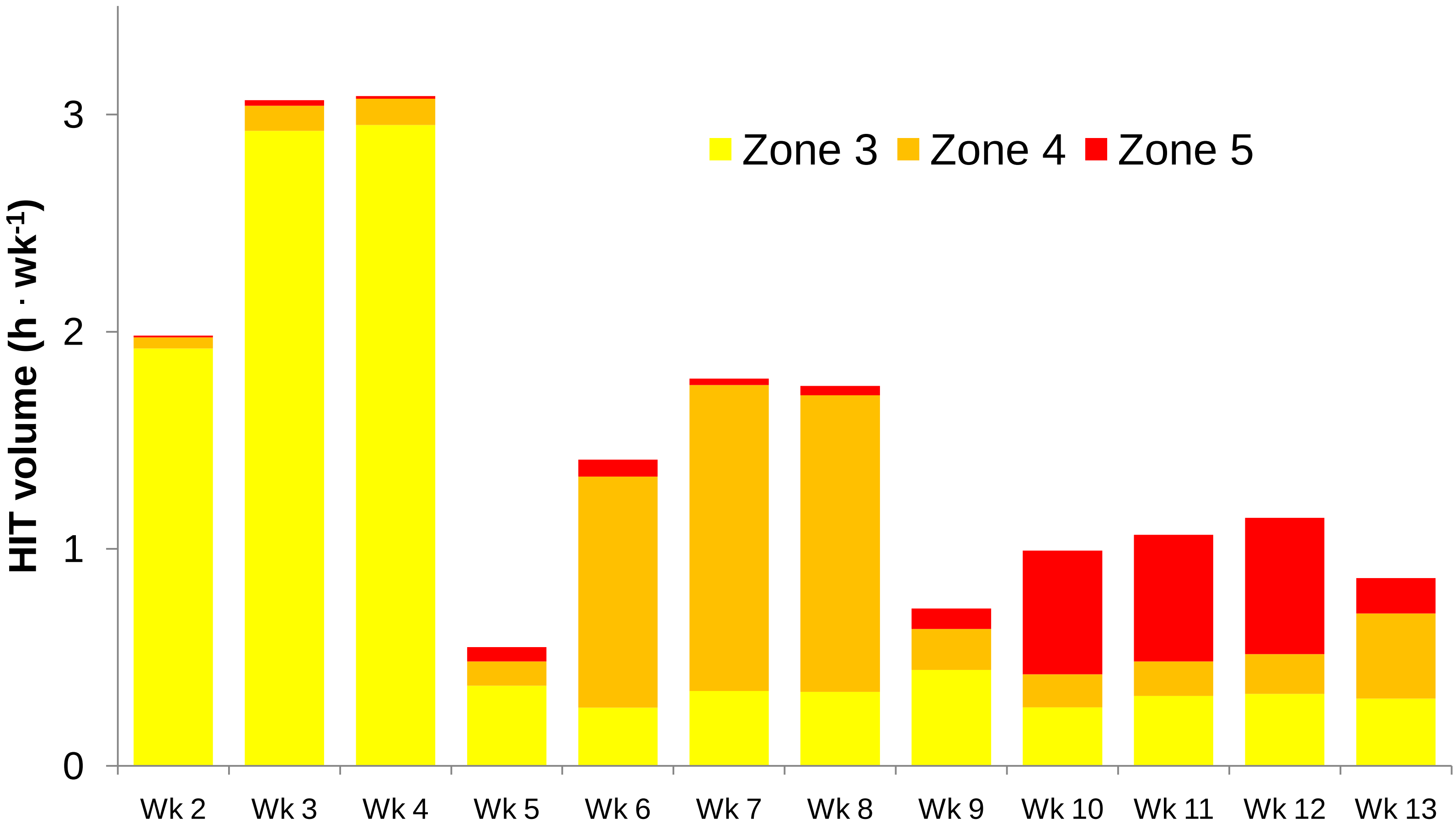
No differences among groups. One-way between-groups ANOVA analysis.

HIT training characteristics of sessions in all subjects during the intervention period. All values are calculated as average (SD) in four laps of up to 24 training sessions.

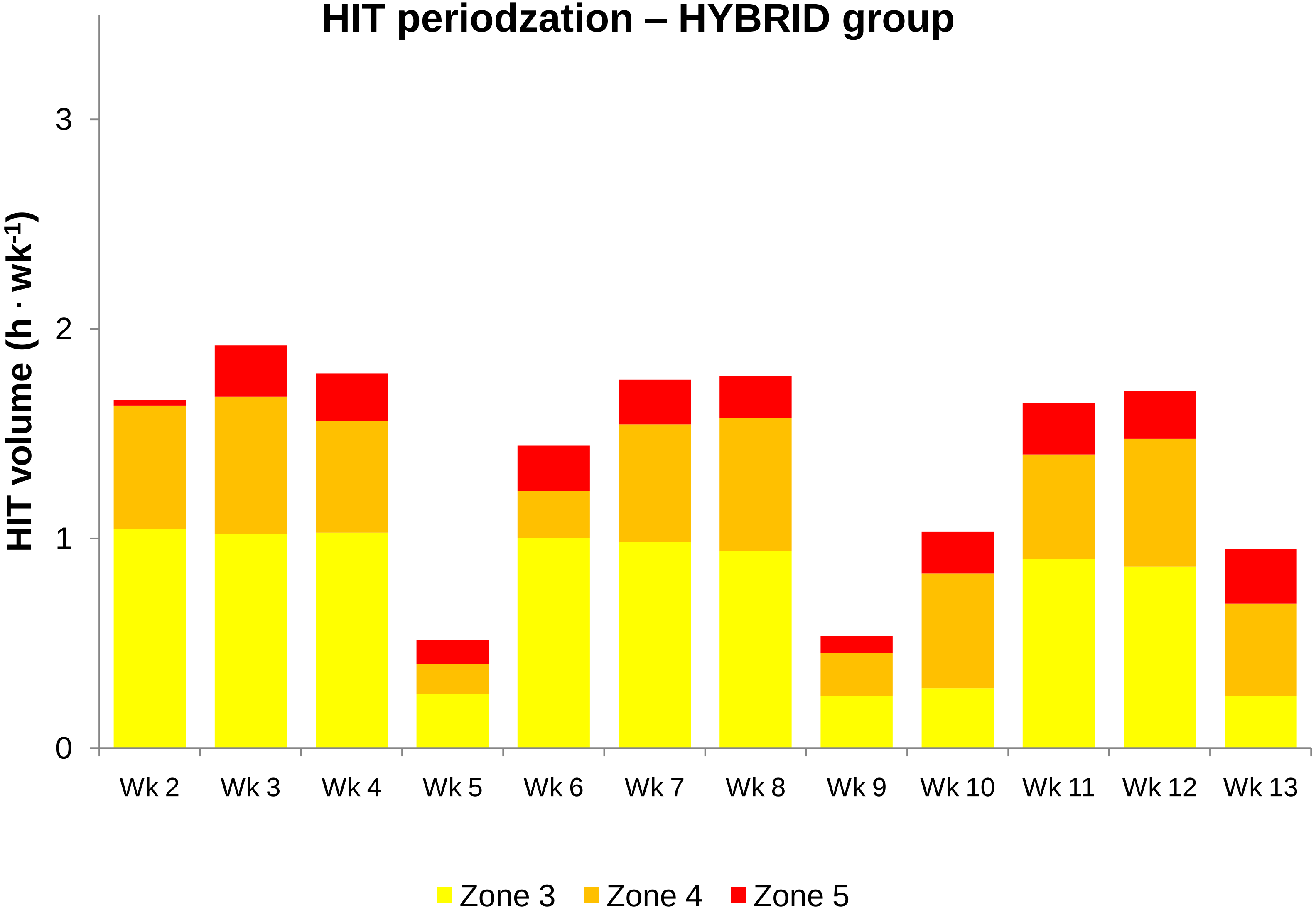
	4x16 (N=63)	4x8 (N=63)	4x4 (N=63)
Power (w)	276 (25)*	308 (29)*	342 (33)*
Power ($w \cdot kg^{-1}$)	3.5 (0.4)*	3.9 (0.4)*	4.3 (0.4)*
Power $_{\%\ 4mM}$ (%)	97 (8)*	106 (8)*	118 (9)*
Blood lactate ($mmol \cdot L^{-1}$)	4.7 (1.6)*	9.2 (2.4)*	12.6 (2.7)*
HR_{mean} (% HR_{peak})	86 (3)*	88 (2)*	89 (2)*
HR_{max} (% HR_{peak})	89 (2)*	91 (2)*	94 (2)*
RPE all bouts, general	15.0 (1.1)*	16.2 (0.8)*	17.1 (0.9)*
sRPE (1-10) 30min post session	6.3 (1.0)*	6.9 (1.0)*	7.7 (1.2)*

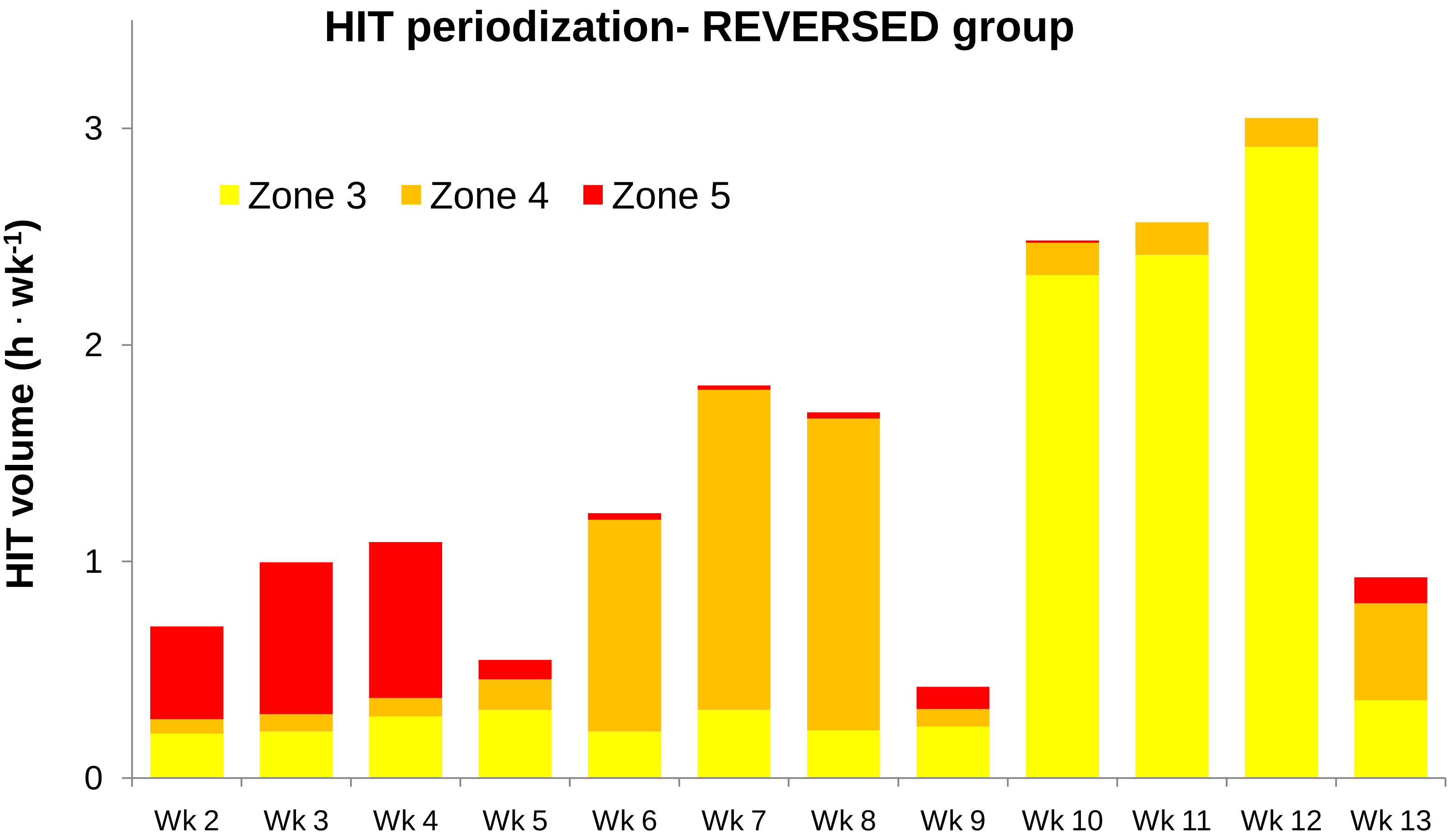
*P<0.001 vs other groups, one-way repeated measures ANOVA.

HIT periodization- TRADITIONAL group

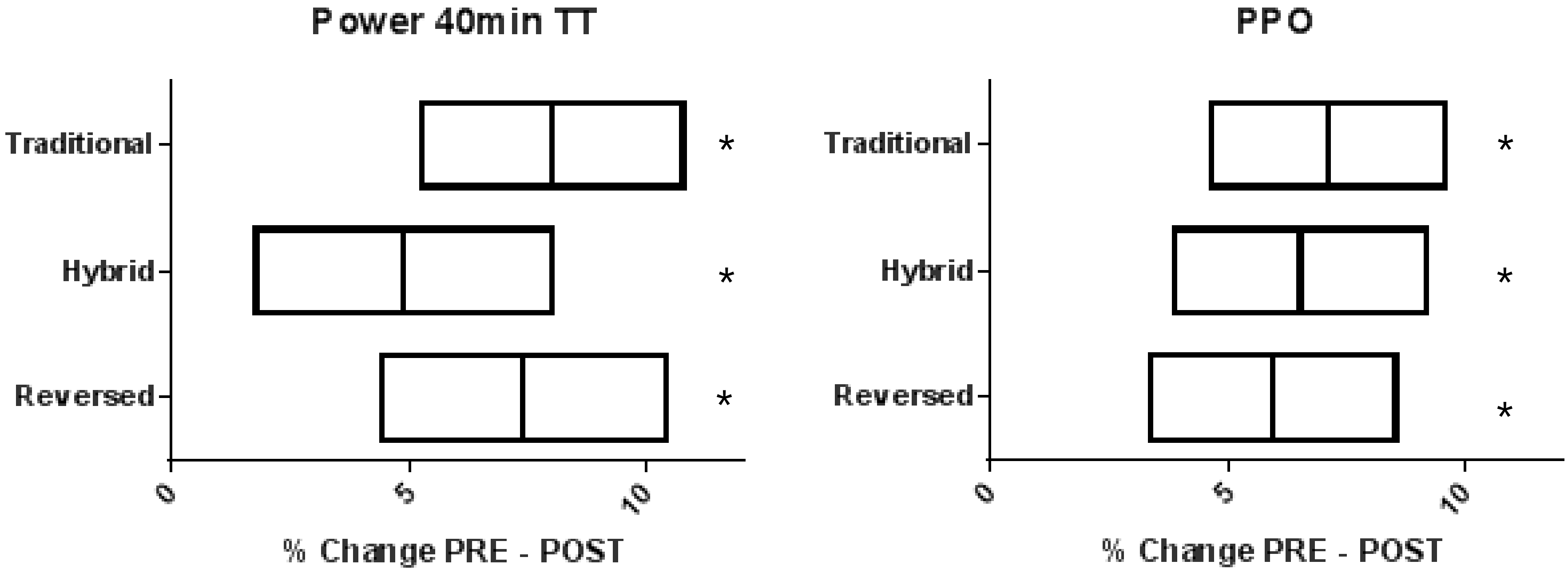


HIT periodzation – HYBRID group

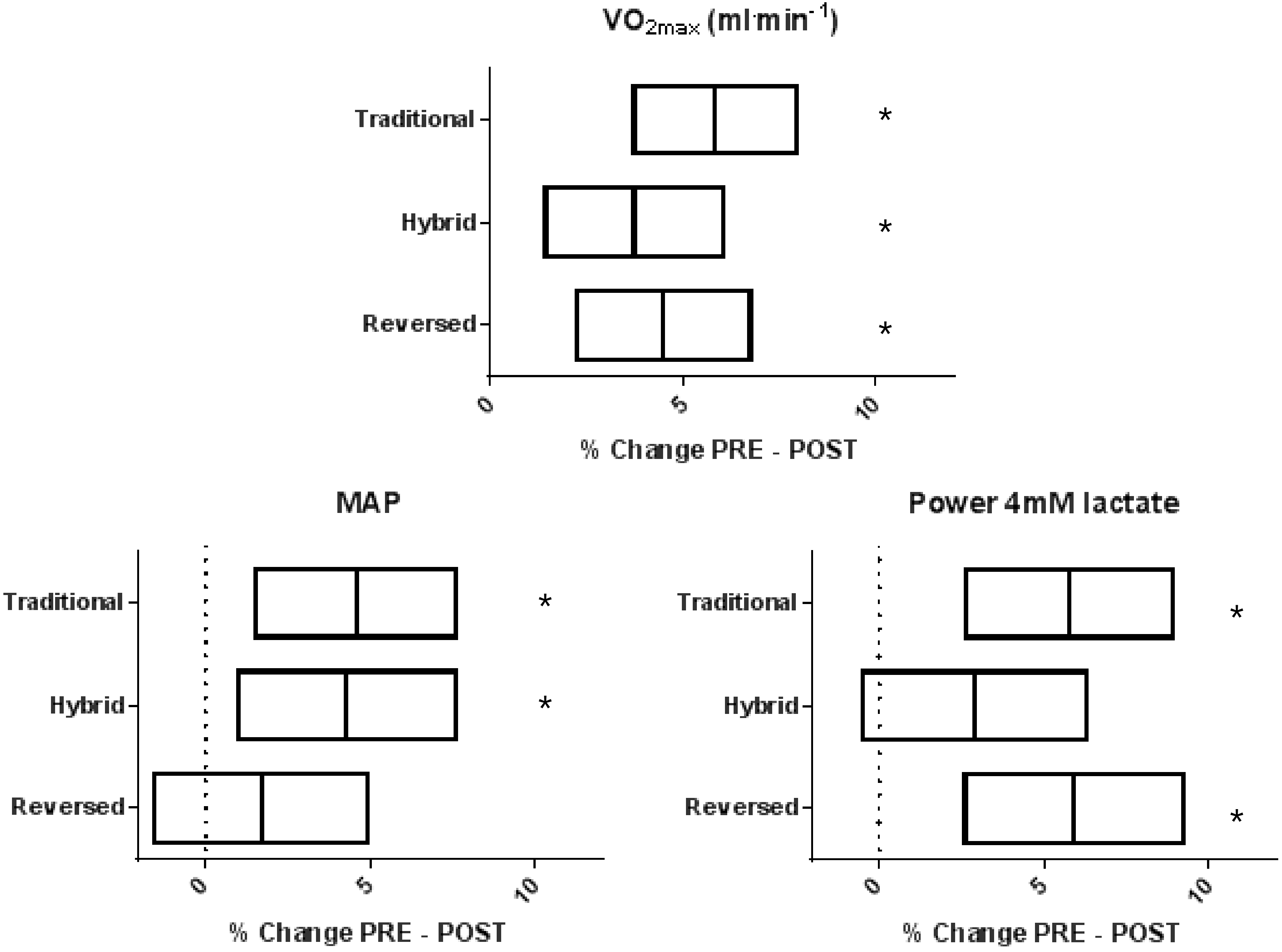



HIT periodization- REVERSED group
HIT volume (h · wk-1)
Zone 3
Zone 4
Zone 5
0
1
2
3
Wk 2
Wk 3
Wk 4
Wk 5
Wk 6
Wk 7
Wk 8
Wk 9
Wk 10
Wk 11
Wk 12
Wk 13

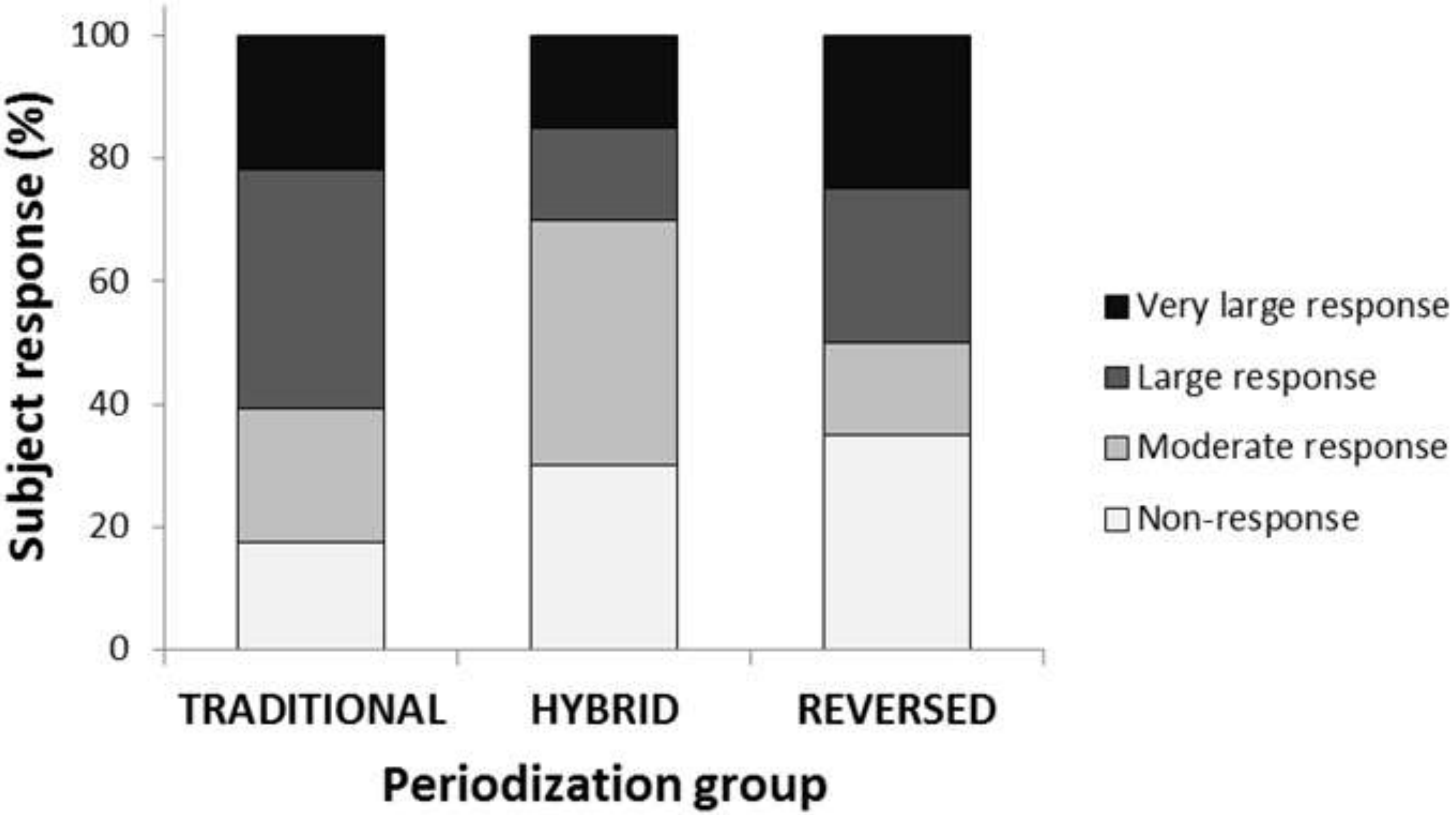
RESULTS



95% CI for relative change. * P < 0.05 vs PRE test. No sig differences between groups. GLM analyses adjusted for group, location and pre 4mM power.

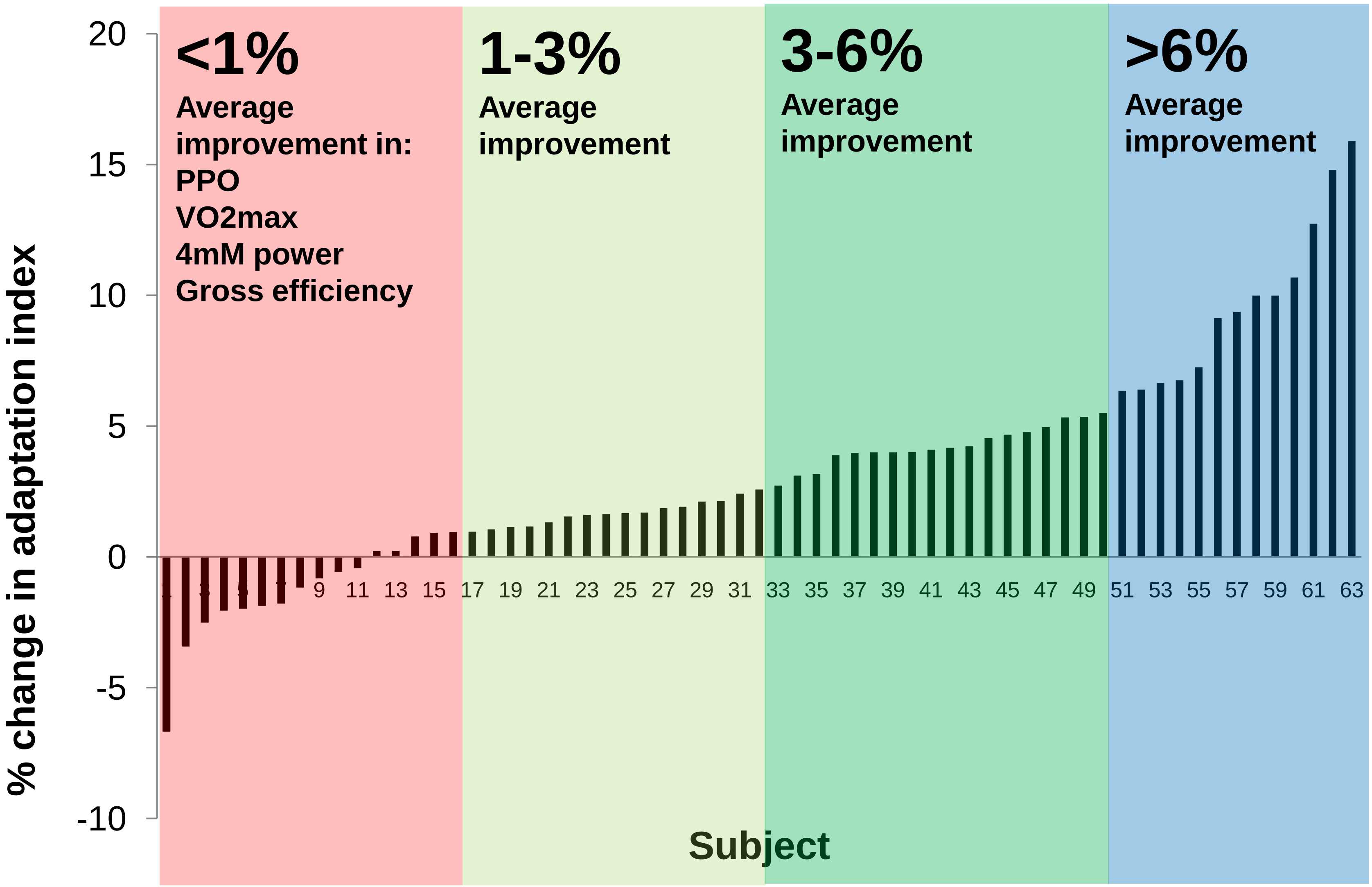


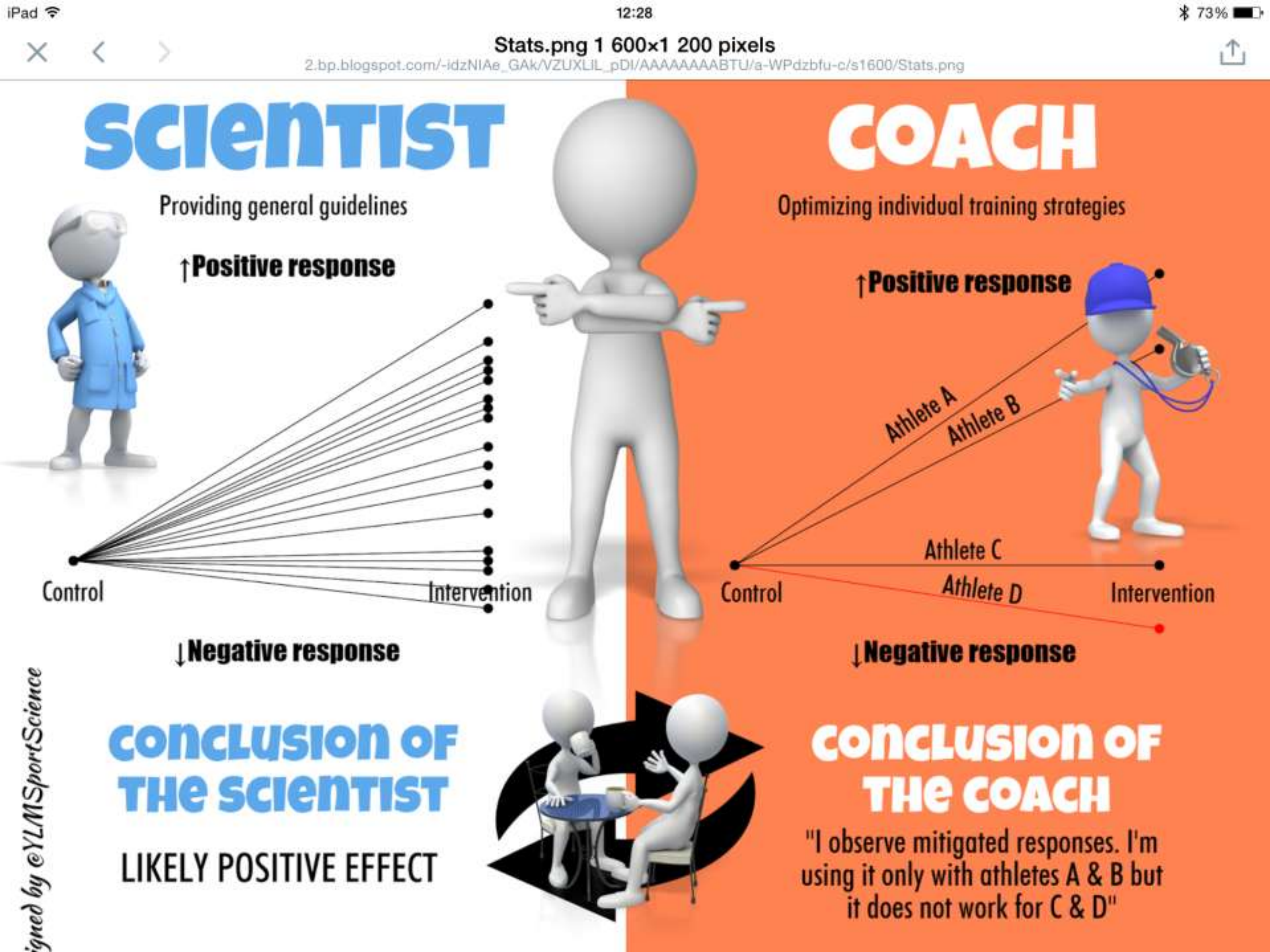
95% CI for relative change. * $P < 0.05$ vs PRE test. No sig differences between groups. GLM analyses adjusted for group, location and pre 4mM power.



Chi-square test for independence indicated no significant association between periodization groups and response distribution.

After 12 weeks of well structured «best practice» training…….




iPad
12:28
73%

Stats.png 1 600×1 200 pixels

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SCIENTIST

Providing general guidelines

↑Positive response
Control
Intervention
↓Negative response

COACH

Optimizing individual training strategies

↑Positive response
Athlete A
Athlete B
Athlete C
Athlete D
Control
Intervention
↓Negative response

CONCLUSION OF THE SCIENTIST

LIKELY POSITIVE EFFECT

CONCLUSION OF THE COACH

"I observe mitigated responses. I'm using it only with athletes A & B but it does not work for C & D"

igned by @YLMSportScience

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