Towards a shared mental model of training for XC skiing

Stephen Seiler PhD
Dept. of Sports Science & Physical Education
University of Agder, Kristiansand, Norway

Mental models

- Understood as a set of organized knowledge structures created by the mind to describe, reason, explain, and anticipate concrete reality to achieve an end goal
- Mental models are working models of the world that humans create to achieve an understanding of their environment
- Refers to the quantity and quality of cognitive, affective, and behavioral knowledge types:
  - What
  - Why
  - Where
  - When
  - How

UiA

Filho & Tenenbaum (2020).

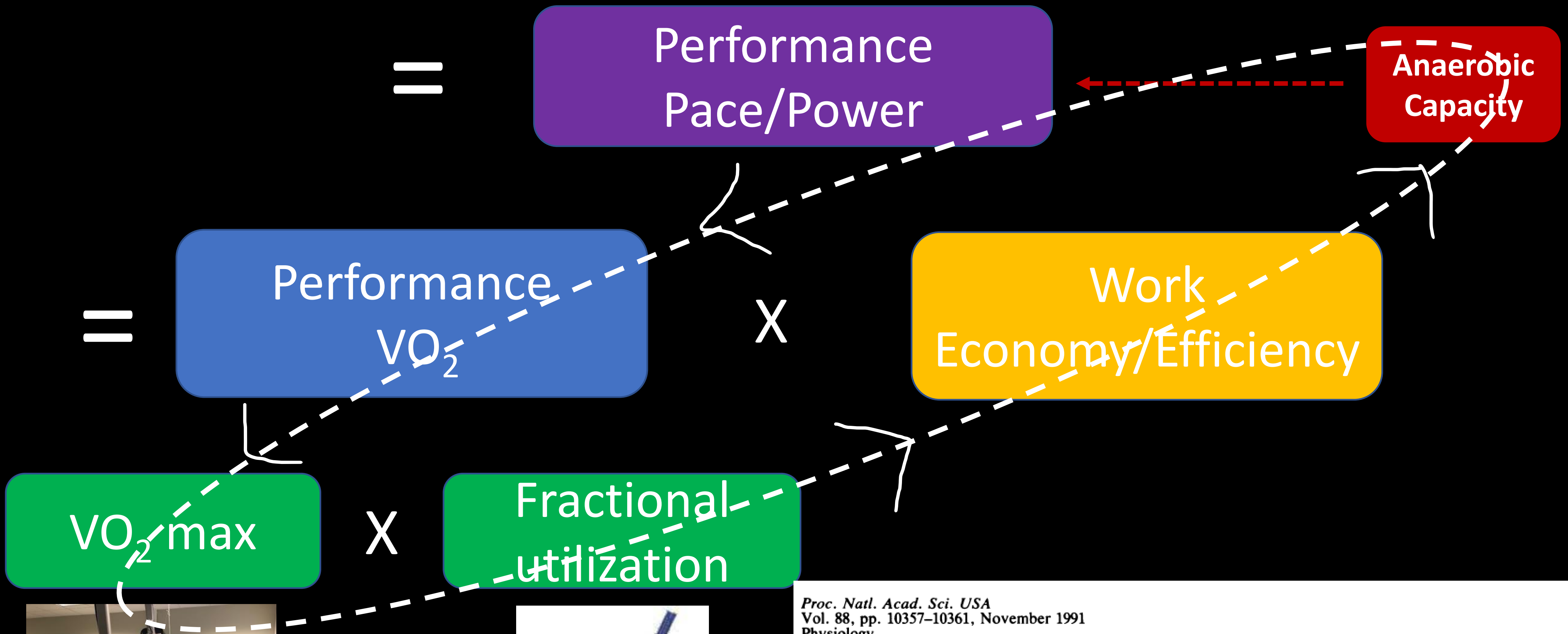
Slide courtesy of Gaute Schei, Dept of Sports Science and Physical education, University of Agder

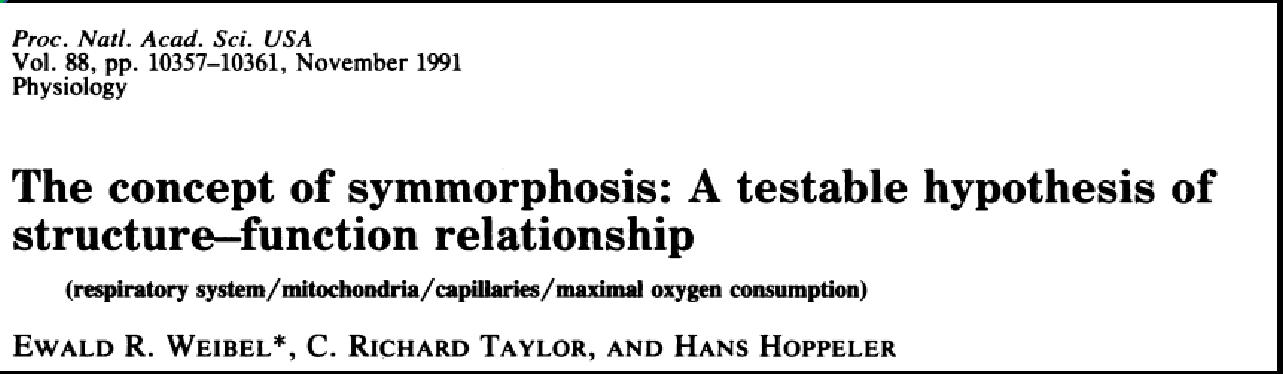
Four Mental models (or one big one)

1. The trainable endurance components and their adaptive time course
2. Maslovian Prioritization: First things First……& Health First
3. Training Intensity Zones as *guardrails* to help optimize signal/stress balance
4. Triangulation in training monitoring

1. What are the *trainable* endurance components?

(And what is the timeline for these adaptations?)



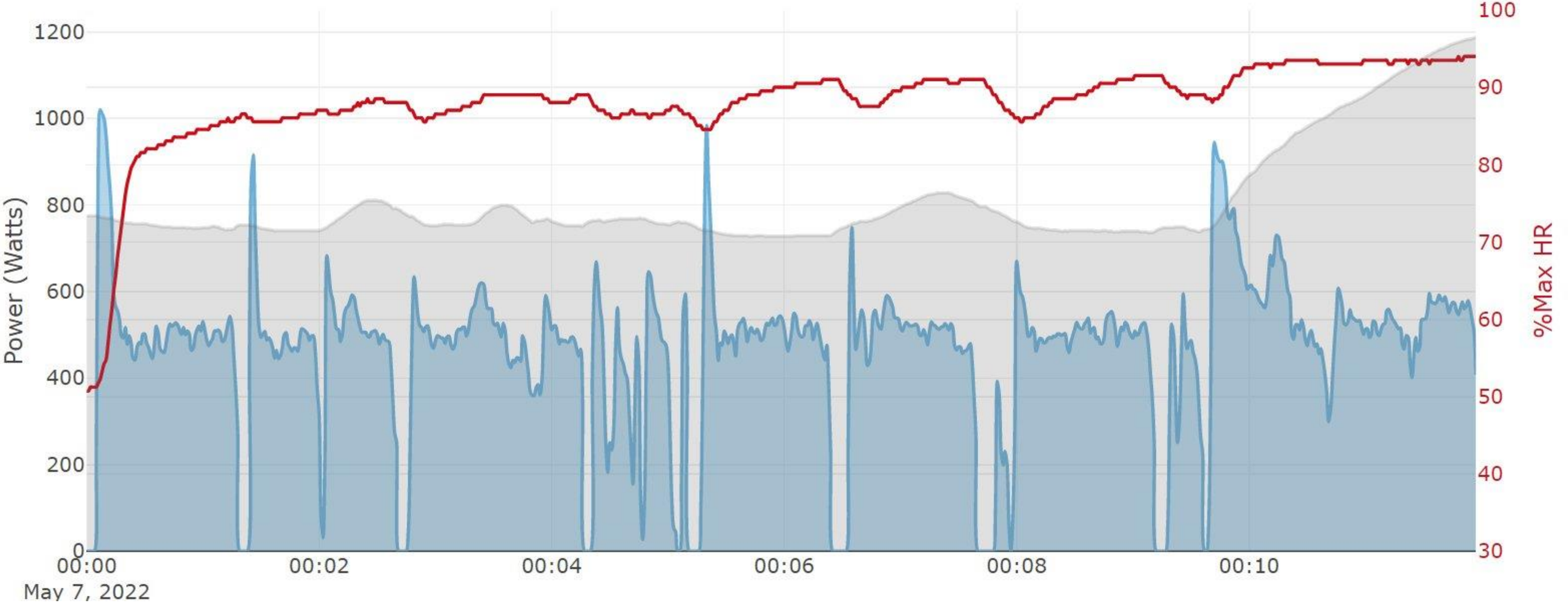

Proc. Natl. Acad. Sci. USA
Vol. 88, pp. 10357–10361, November 1991
Physiology

The concept of symmorphosis: A testable hypothesis of structure–function relationship

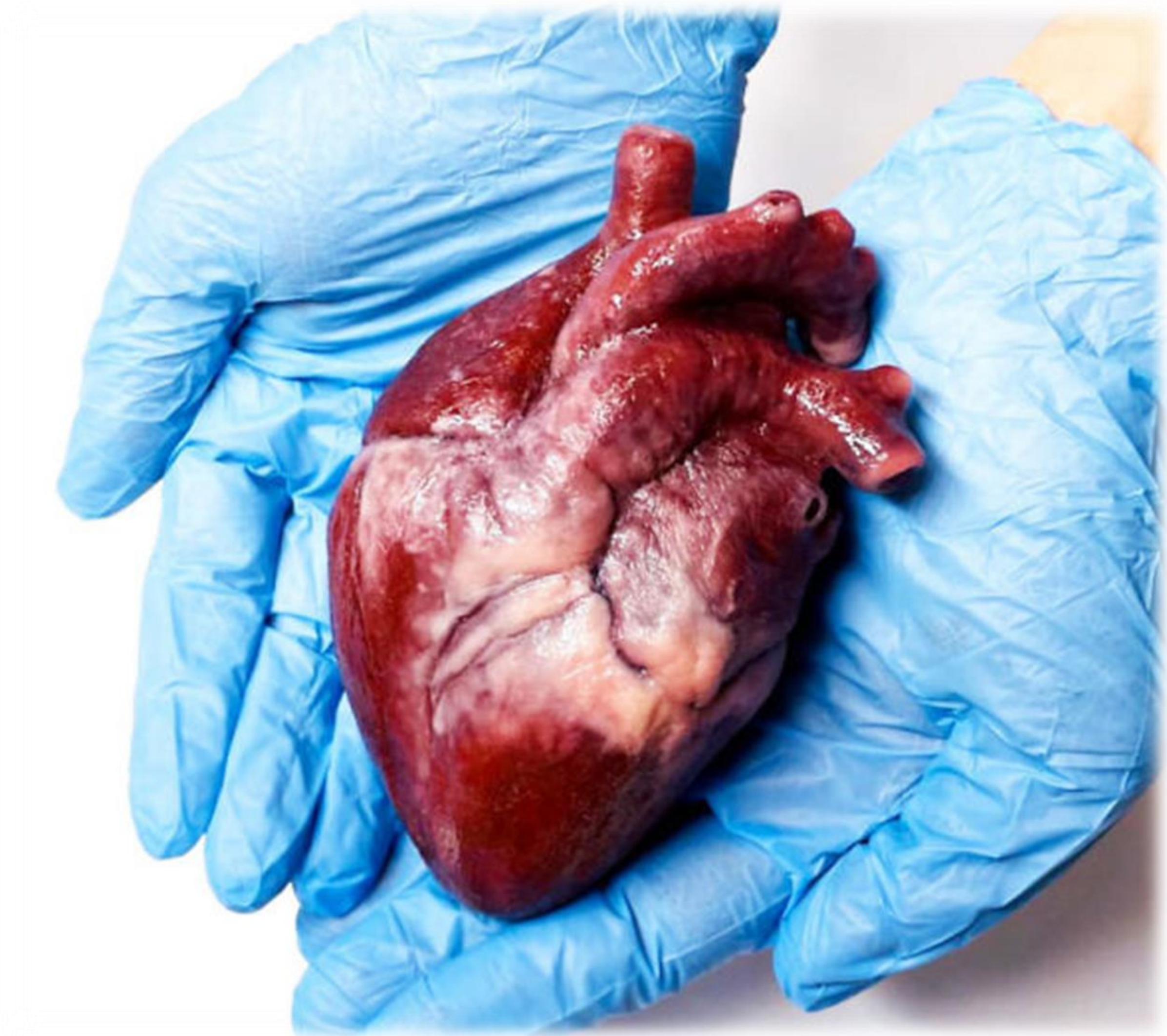
(respiratory system/mitochondria/capillaries/maximal oxygen consumption)

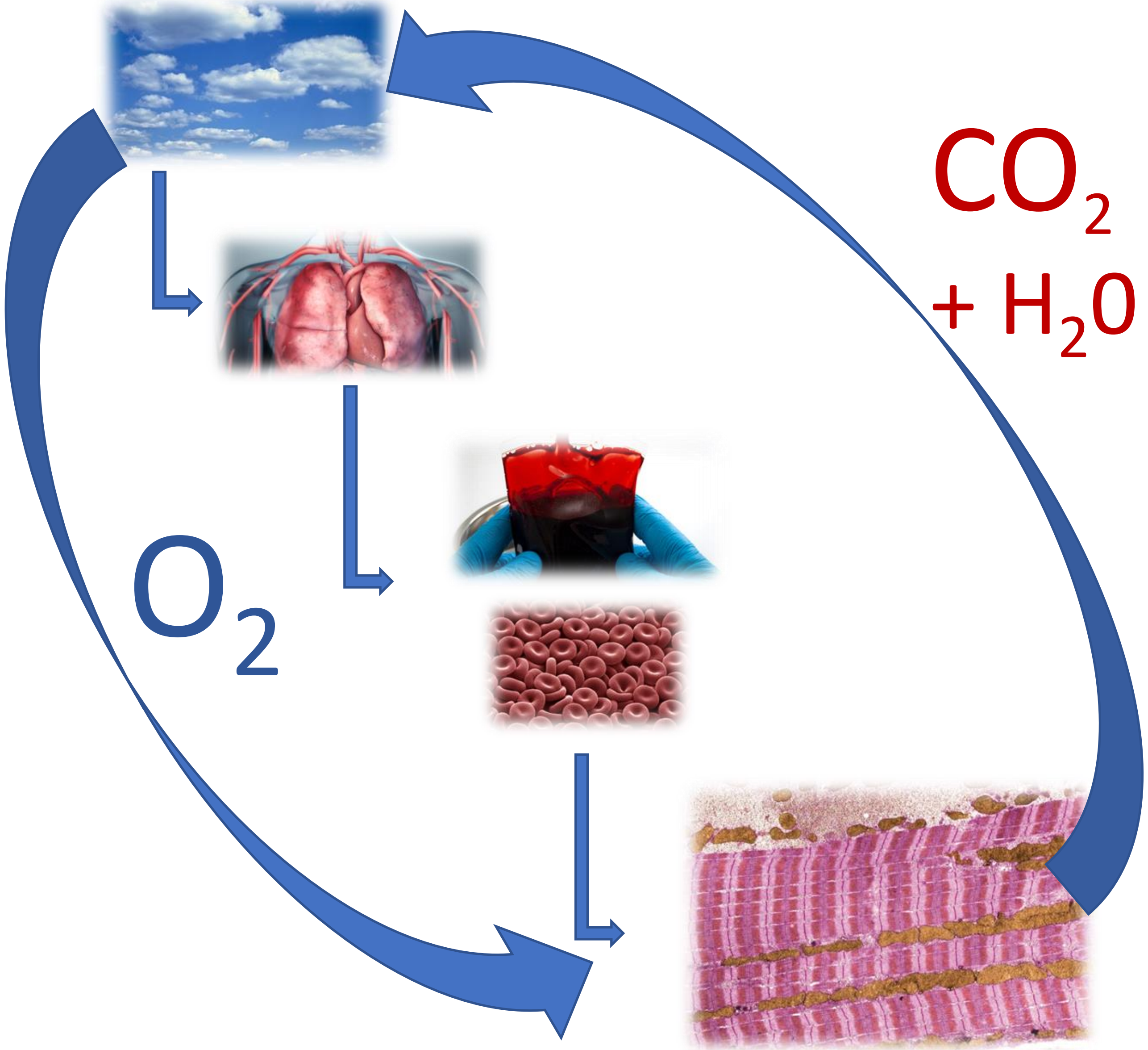
EWALD R. WEIBEL*, C. RICHARD TAYLOR, AND HANS HOPPELER

What type of race is this?



The body cannot use more oxygen than the heart can deliver





VO_2 max vs VO_2 peak: Role of muscle mass activation

JOURNAL OF APPLIED PHYSIOLOGY
Vol. 41, No. 2, August 1976. *Printed in U.S.A.*

Maximal oxygen uptake during exercise with various combinations of arm and leg work

U. BERGH, I.-L. KANSTRUP, AND B. EKBLOM
Department of Physiology, Gymnastik- och Idrottshögskolan, Stockholm, Sweden

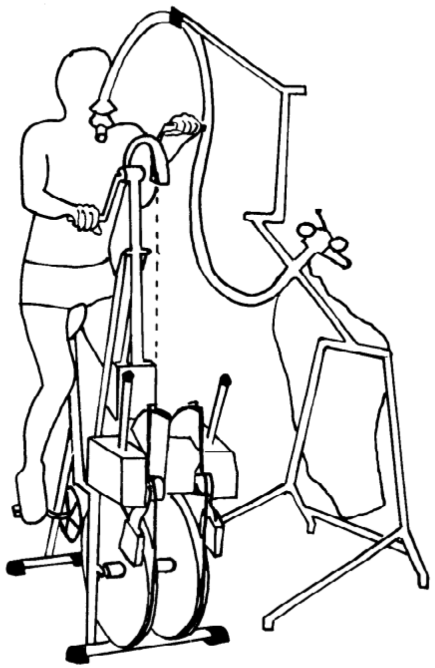


FIG. 1. Bicycle ergometer constructed with two independent braking systems for combined or separate arm and leg work.

TABLE 2. *Maximal values for oxygen uptake, heart rate, pulmonary ventilation, ventilatory quotient, blood lactate, and work time during different types of exercise*

	Running	Arm Cycling	Leg Cycling	Arm + Leg Work, Proportion of arm work: 10%	20%	30%	40%
$\dot{V}O_{2\,max}$, $l \cdot min^{-1}$	**4.44**	**3.01**	**4.12**	4.32‡ ±0.56	4.34 ±0.50	4.27 ±0.46	4.01* ±0.53
% of $\dot{V}O_{2\,max}$, running	**100%**	**70%**	**93%**	97.4 ±3.6	98.1 ±3.6	96.6 ±5.4	90.6 ±6.9
Heart rate, $beats \cdot min^{-1}$	**193**	**176**	**189**	188† ±8.8	189† ±8.3	187* ±9.7	185* ±9.7

~210-220sec work duration

~210-220sec work duration

Muscle mass activation > cardiac pumping capacity

Cardiac Pumping Capacity > upper body muscle mass activation …..**Unless**….

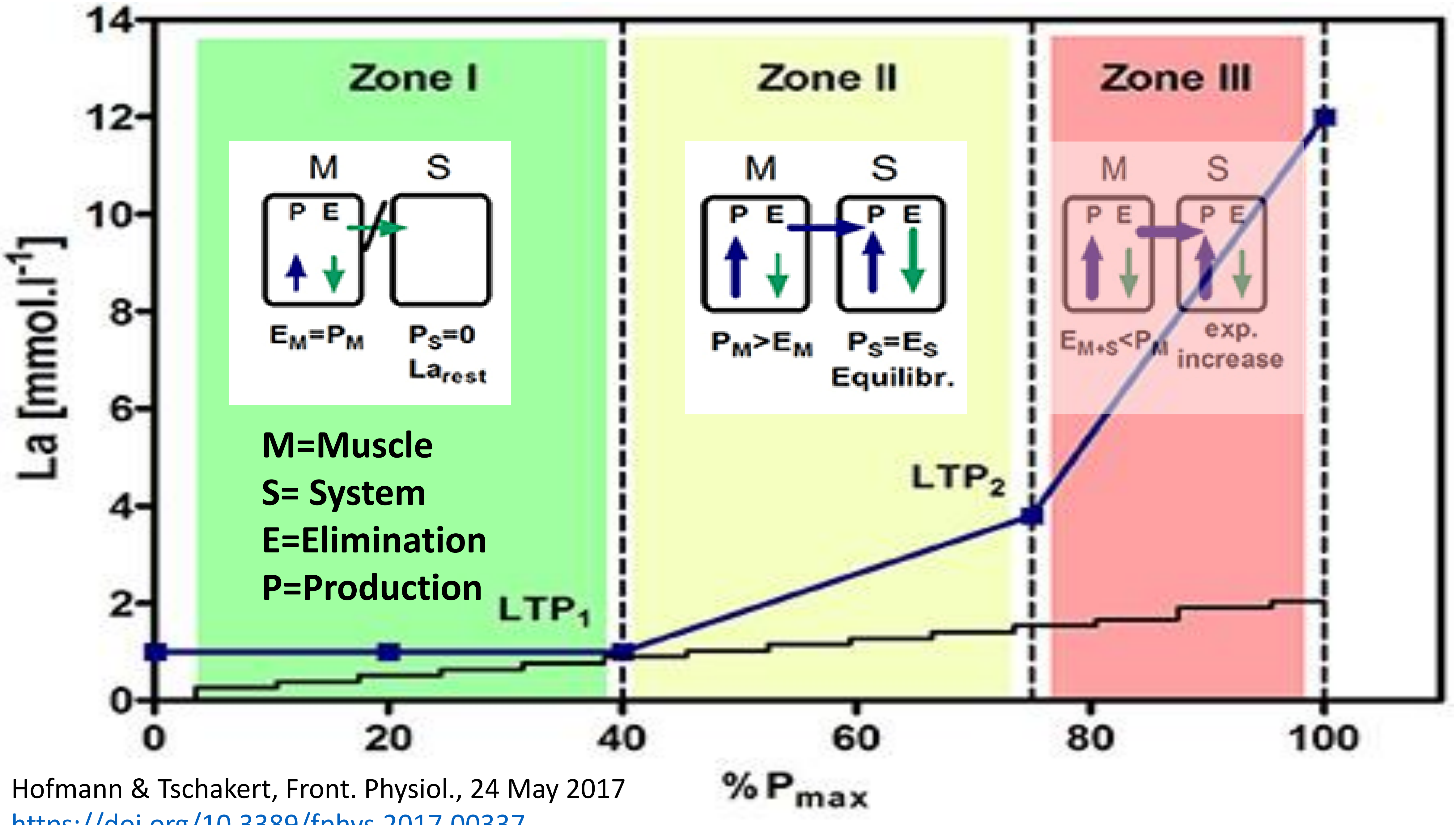
Eliud Kipchoge 2:01:09

Marcel Hug: 1:17:47

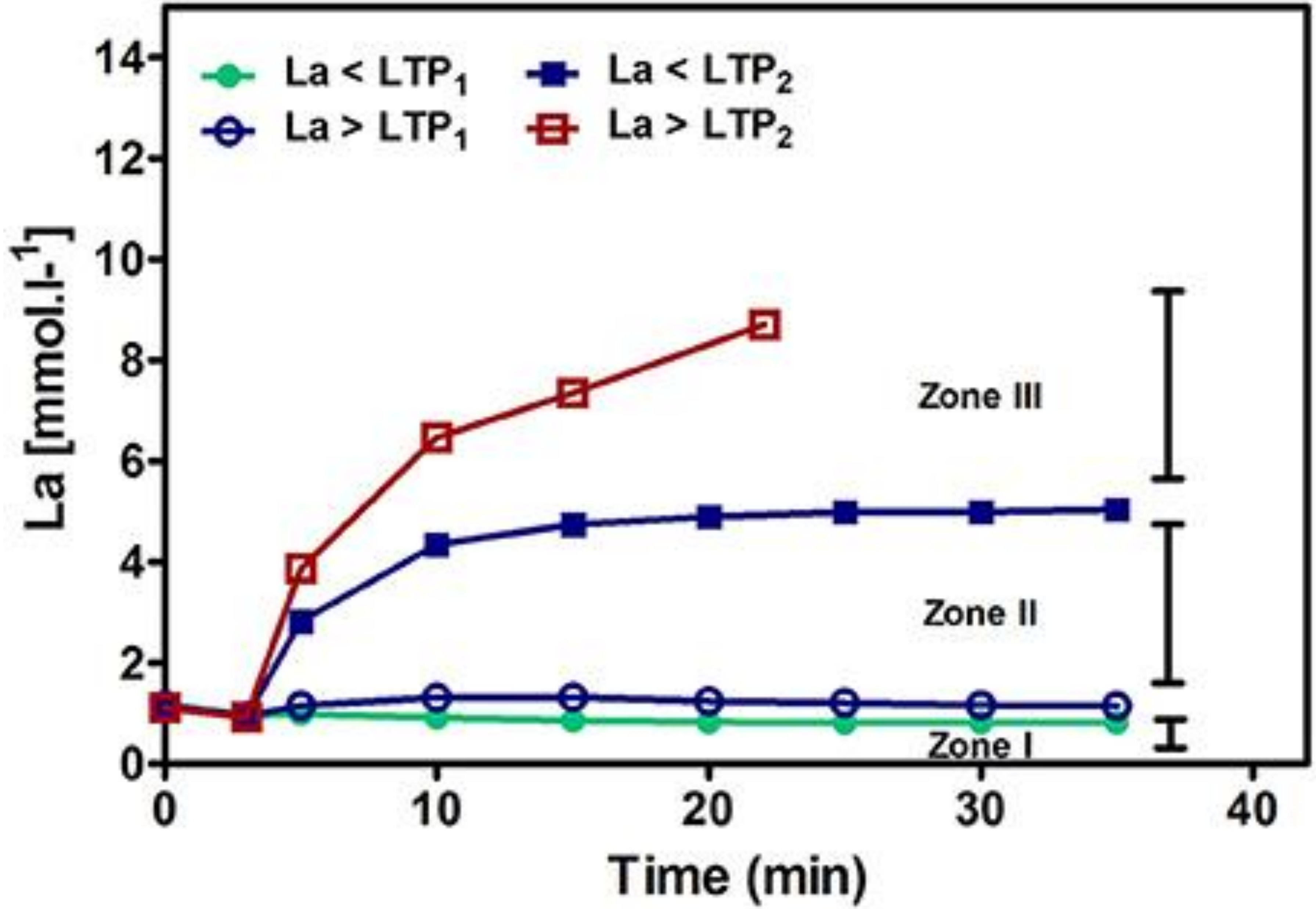

51
41
21
CRAFT
FISCHER
swix

What *fraction*, or percentage, of their **Maximal Oxygen Consumption** can the athlete utilize “for a relatively long time*” without having to slow down?

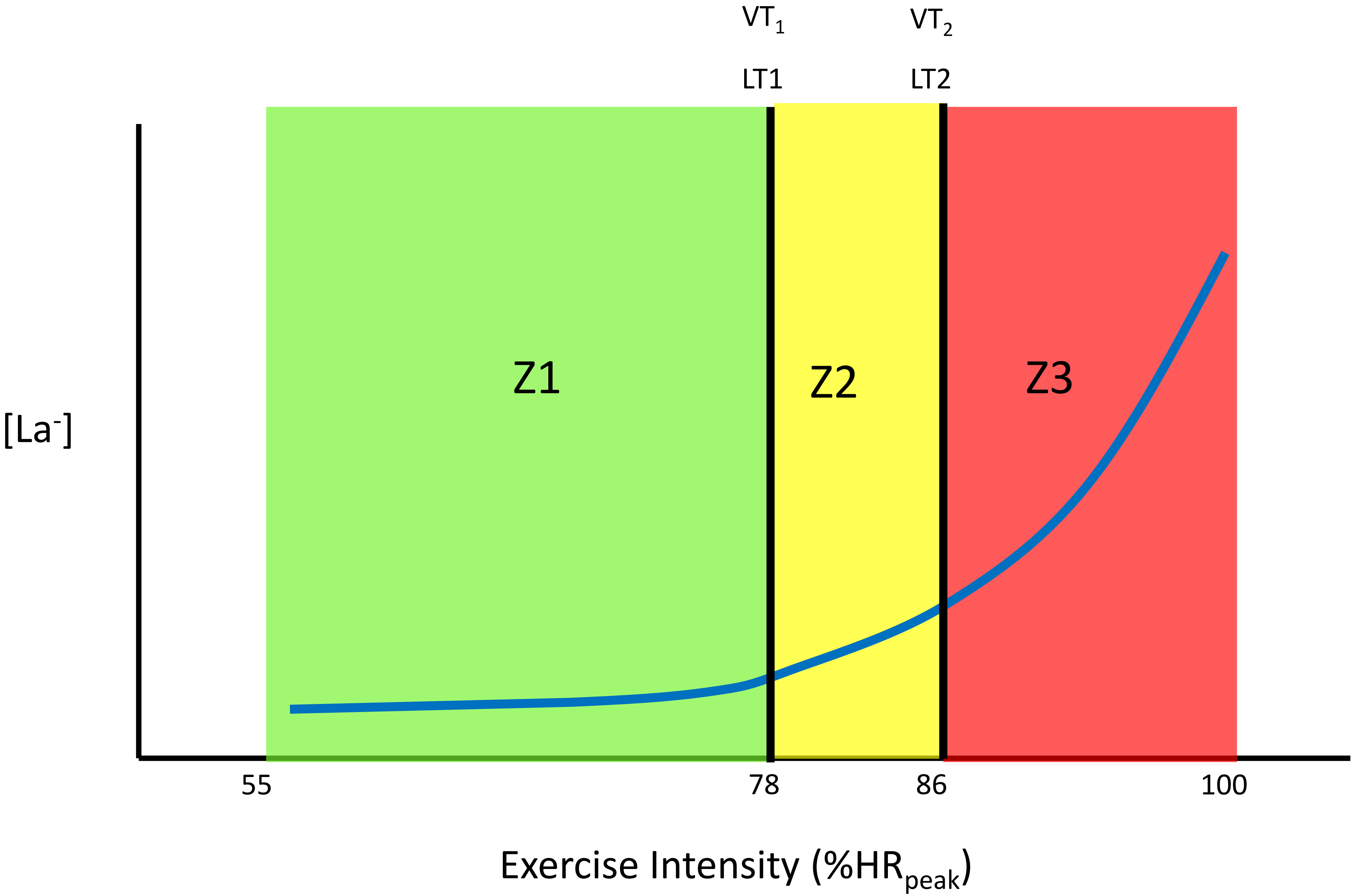
*(~30 minutes to ~2 hours)



Hofmann & Tschakert, Front. Physiol., 24 May 2017
https://doi.org/10.3389/fphys.2017.00337



Hofmann & Tschakert, Front. Physiol., 24 May 2017
https://doi.org/10.3389/fphys.2017.00337



VT1
LT1
VT2
LT2
Z1
Z2
Z3
[La-]
55
78
86
100
Exercise Intensity (%HRpeak)

SESSION TYPE	HR (%MAX)	VO_2 (%MAX)	BLOOD LACTATE (mM)	RPE (BORG 6-20)	SESSION RPE (FOSTER 1-10)
BELOW VT_1 60MIN	**68 ± 7**	**61 ± 0.7**	**1.0 ± 0.1**	**9.7 ± 0.4**	**2 ± 0**
BELOW VT_1 120 MIN	**68 ± 7**	**Not measured, ran outdoors**	**1.0 ± 0.1**	**10 ± 0.4**	**2.4 ± 1.1**
THRESHOLD	**88 ± 2**	**84 ± 0.7**	**2.7 ± 0.4**	**13.9 ± 0.5**	**5 ± 0.6**
ABOVE VT_2 (6 X 3MIN)	**95 ± 3**	**96 ± 0.7**	**7.1 ± 0.7**	**17.2 ± 0.8**	**8.1 ± 1**

Autonomic recovery after exercise in trained athletes: intensity and duration effects
S Seiler, O Haugen, E Kuffel
Medicine & Science in Sports & Exercise 39 (8), 1366-1373

The Physiology of the World Record Holder for the Women's Marathon

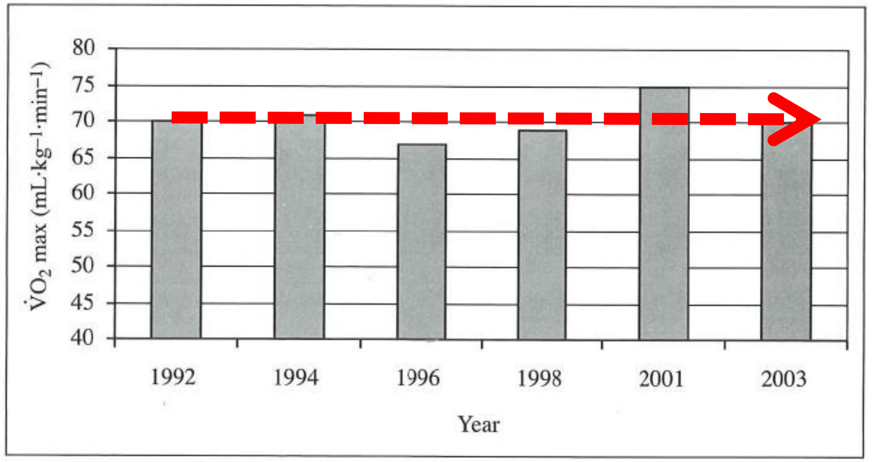
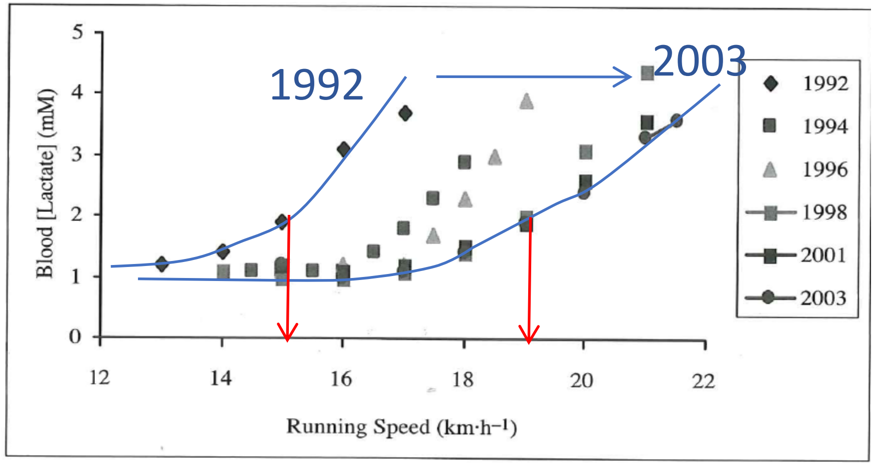
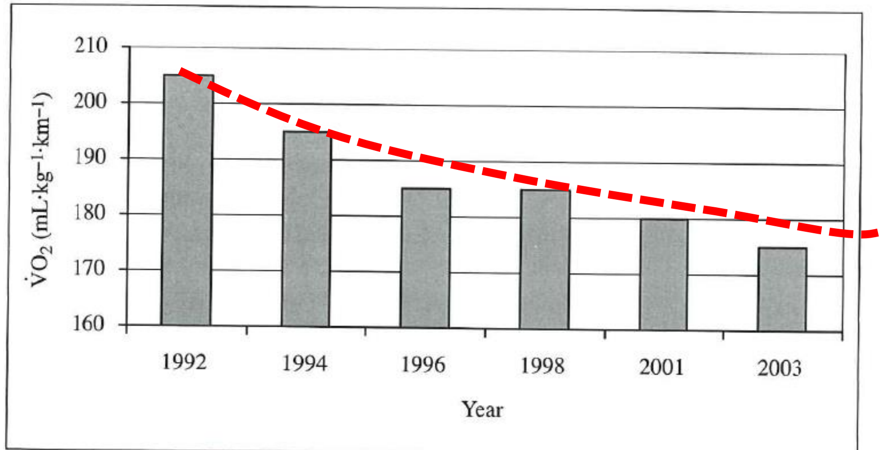


Figure 3. PR's $\dot{V}O_2$ max Values, 1992-2003

No change in VO_2max



25% increase in velocity at 2mM blood lactate



15% improvement in running economy

Paula Radcliffe, 2:15:25 WR Marathon

Jones, AM. Int. J. Sports Science & Coaching 1(2), 2006.

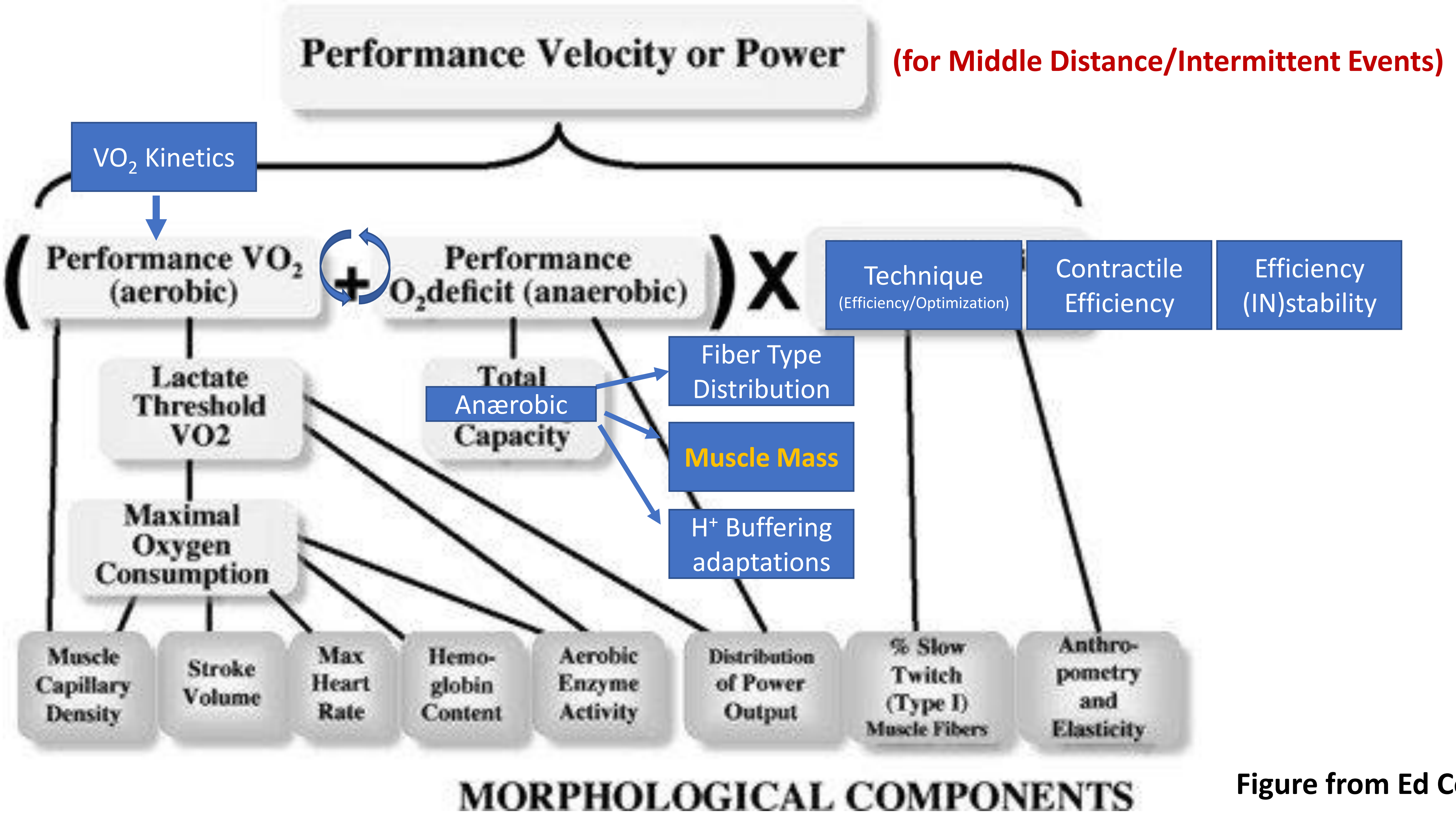
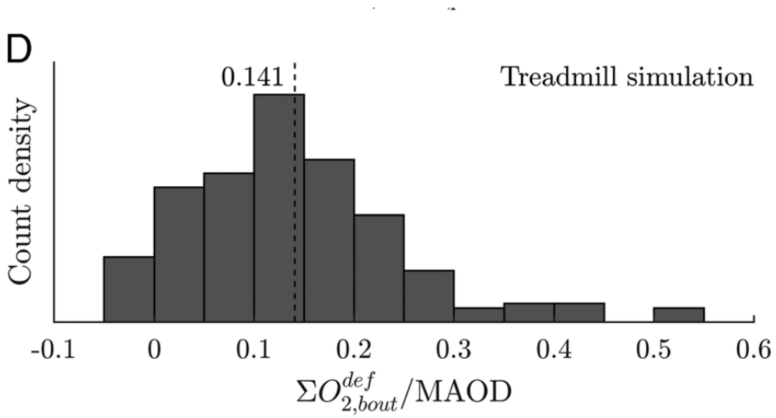


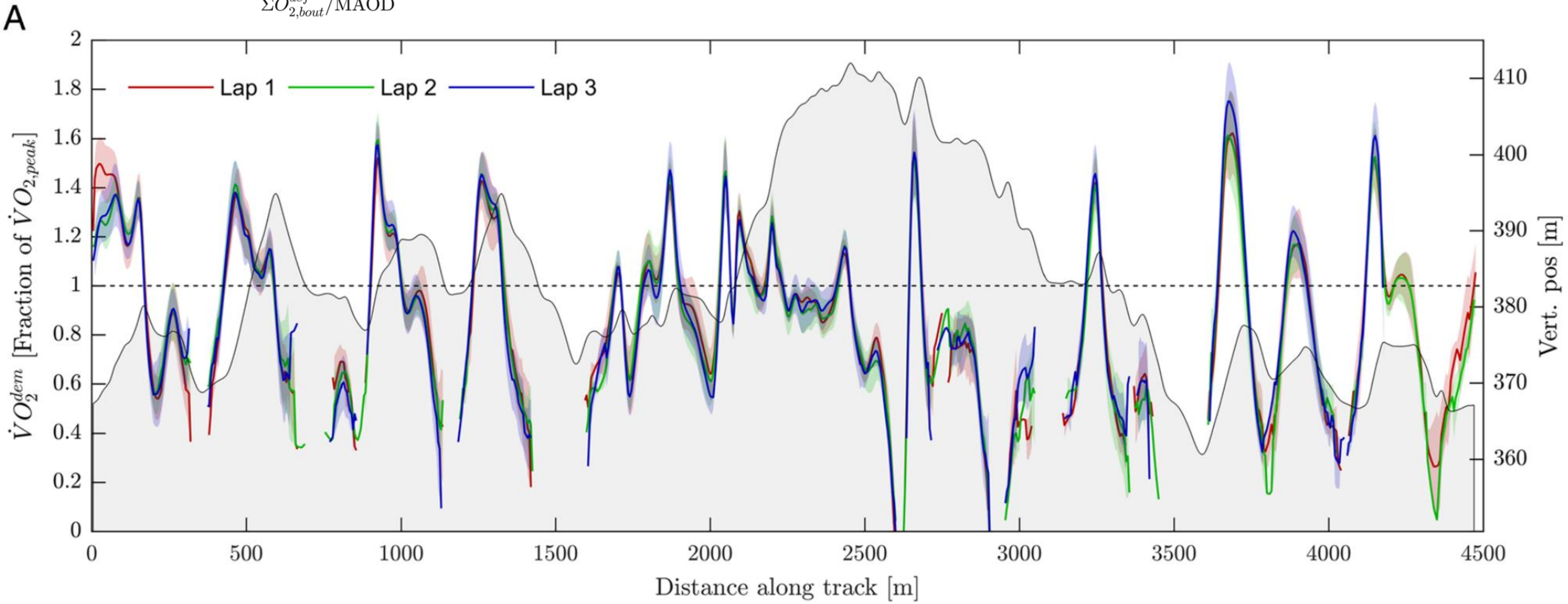
Figure from Ed Coyle

Oxygen Demand, Uptake, and Deficits in Elite Cross-Country Skiers during a 15-km Race

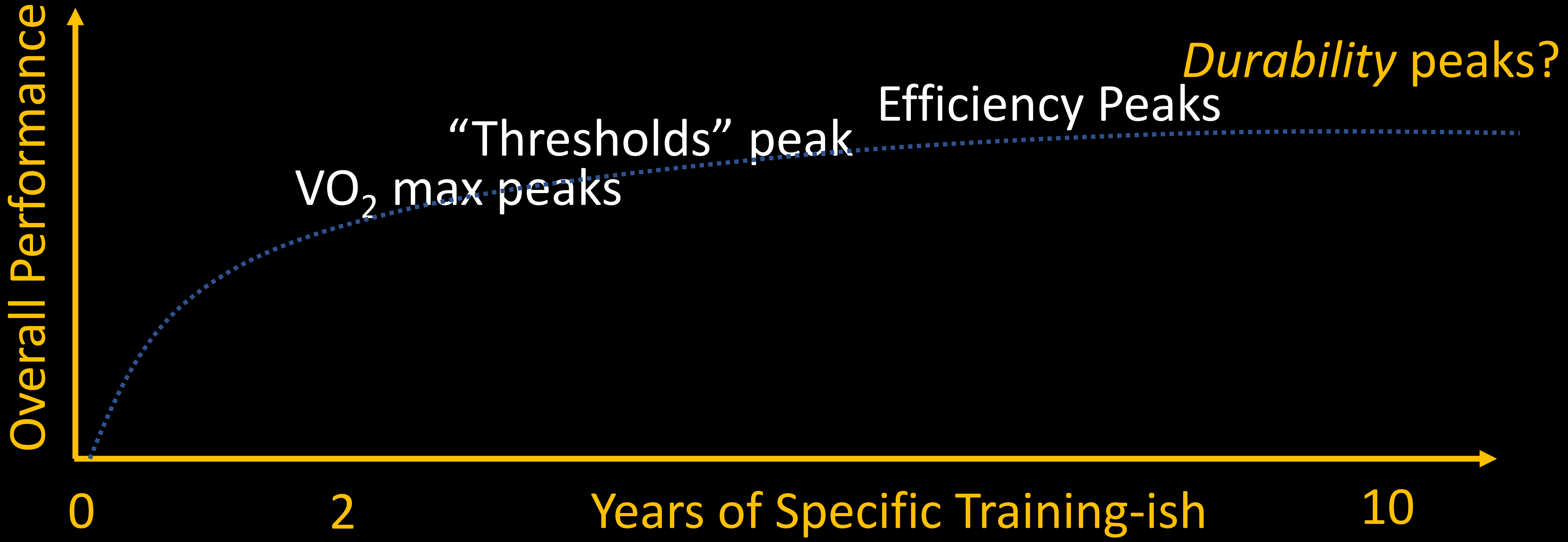
ØYVIND GLØERSEN[1,2], MATTHIAS GILGIEN[2,3], DAG KRISTIAN DYSTHE[1], ANDERS MALTHE-SØRENSSEN[1,4], and THOMAS LOSNEGARD[2]

Med. Sci. Sports Exerc., Vol. 52, No. 4, pp. 983–992, 2020.





Different time courses to peak adaptation…….

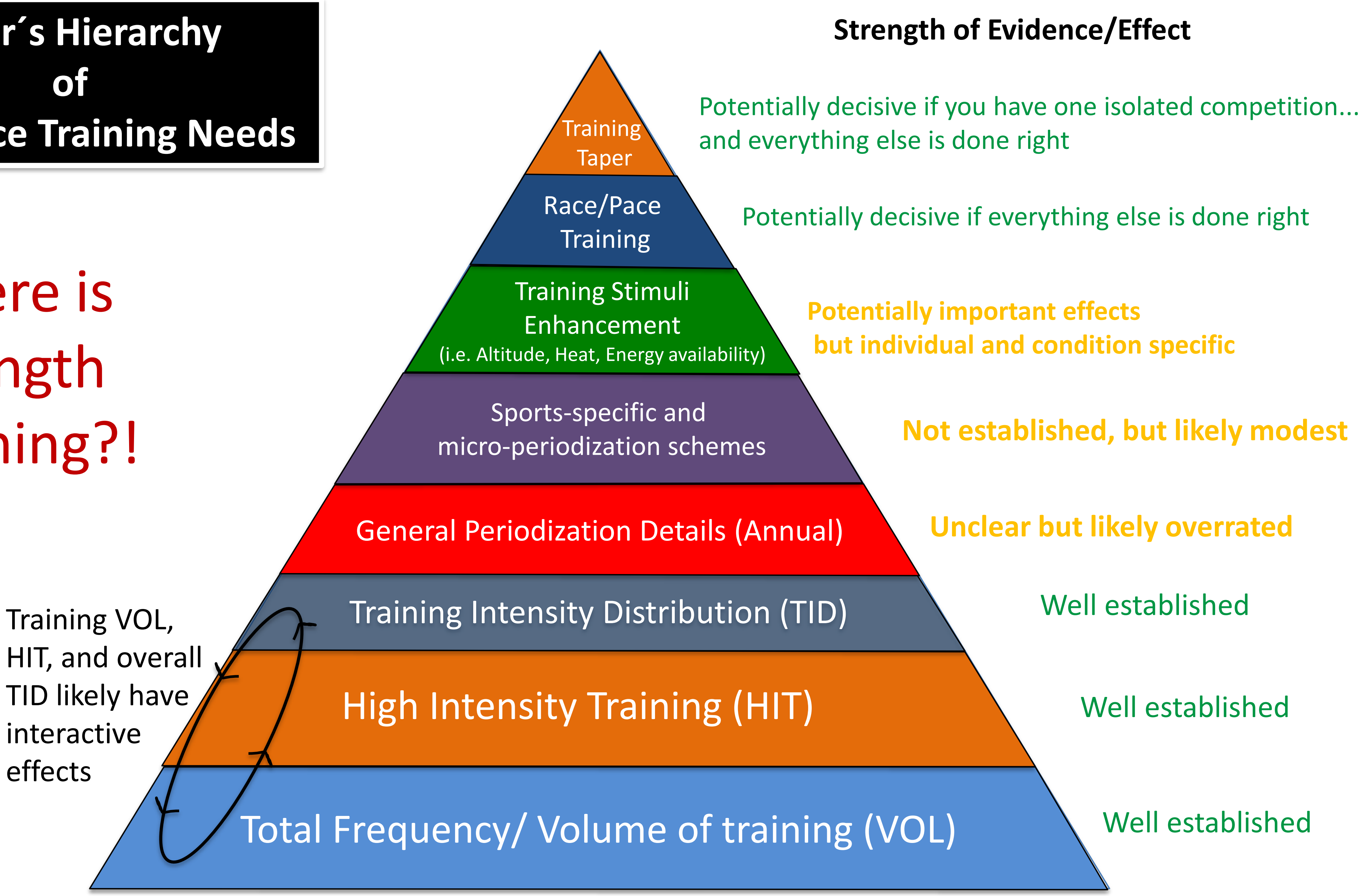


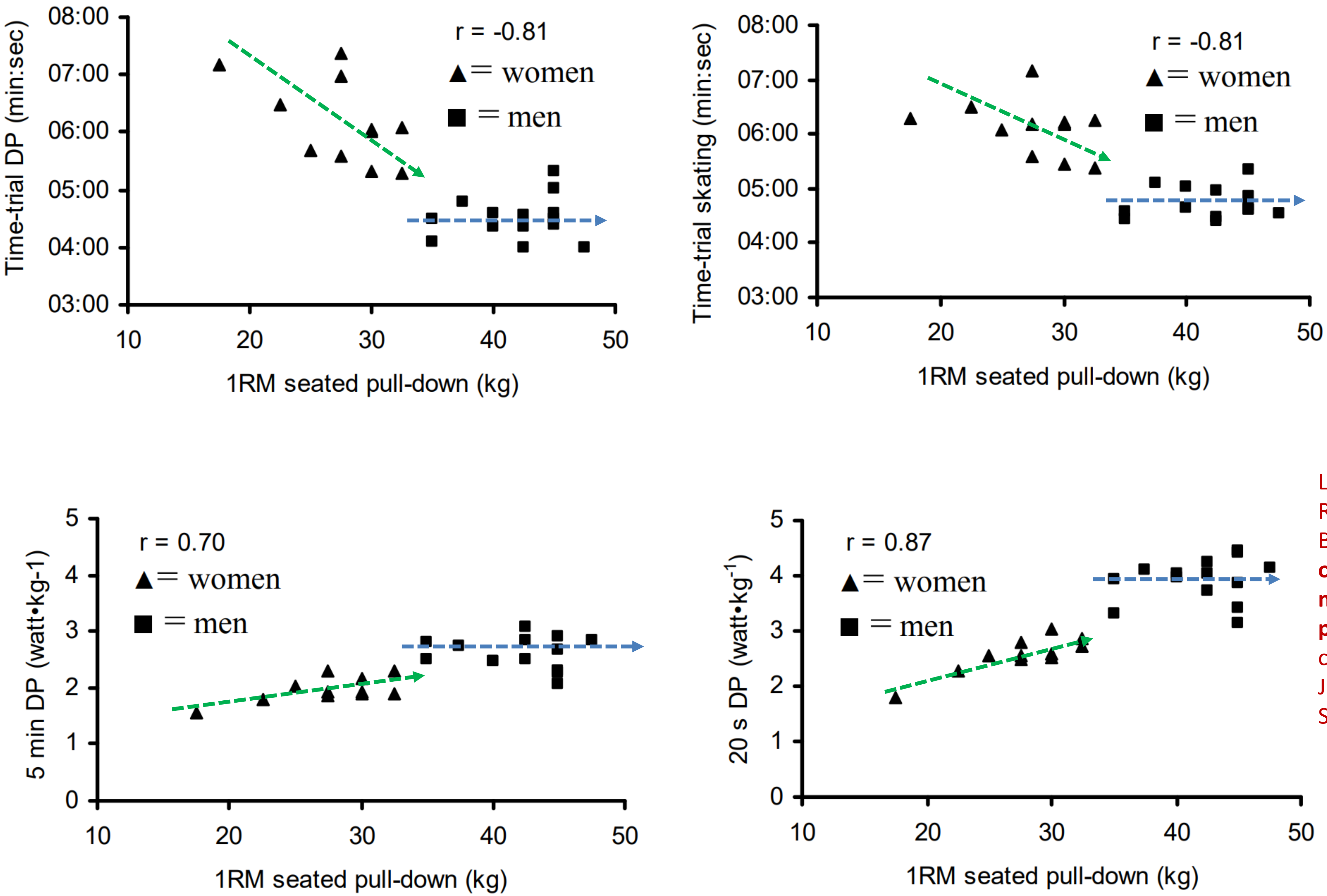
2. *Maslovian* Prioritization:

First things First
and
Staying *healthy* is Priority One

Seiler´s Hierarchy of Endurance Training Needs

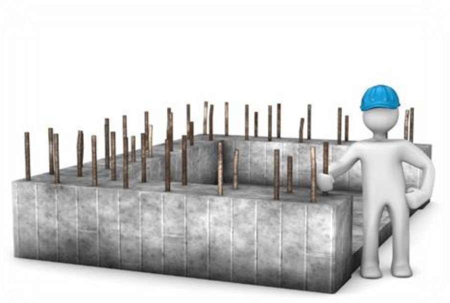
Where is Strength Training?!





Losnegard, T., Mikkelsen, K. L., Rønnestad, B. R., Hallén, J., Rud, B., Raastad, T. (2011). **The effect of heavy strength training on muscle mass and physical performance** in elite cross country skiers. Scandinavian Journal of Medicine & Science in Sports, 21, 389-401.

Your training methods and execution



OR

Work/School stress

Aging!

Physical & Mental Health

Infections

"Parenting Stress"

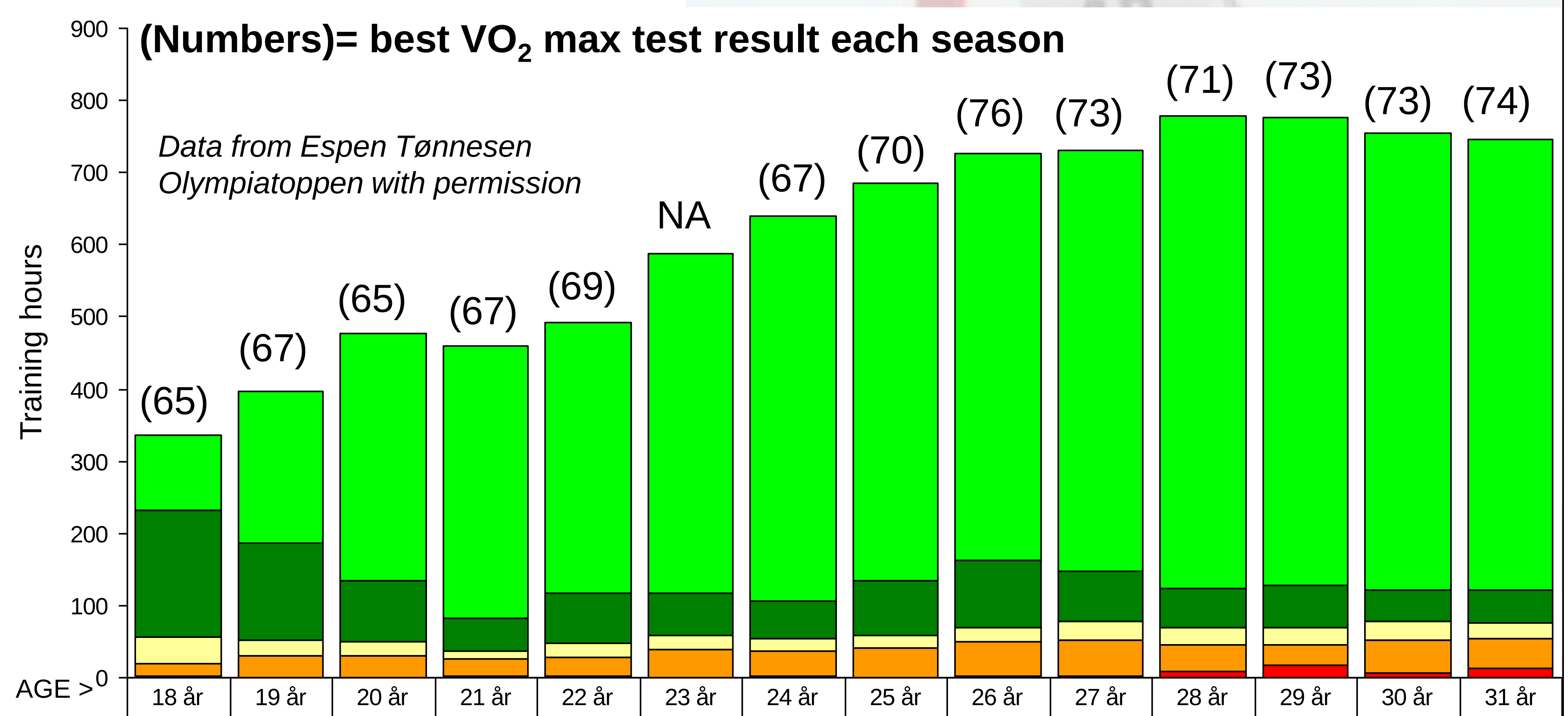
"Relationship Stress"

Sleep

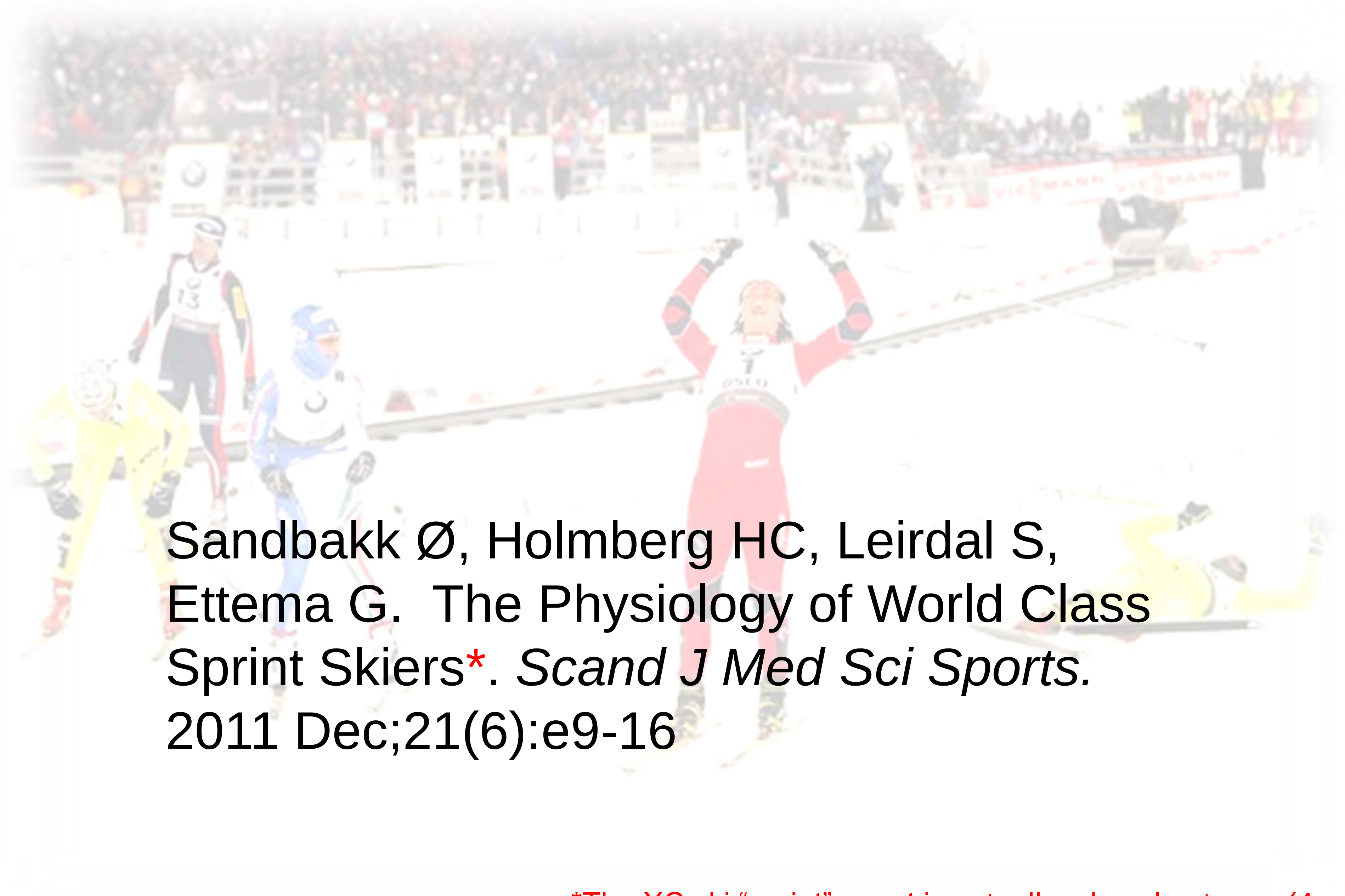
Nutrition

Injuries

Bente Skari
5 time World Champion, O-gold, 42 WC victories



	18 år	19 år	20 år	21 år	22 år	23 år	24 år	25 år	26 år	27 år	28 år	29 år	30 år	31 år
I-sone 1	103	211	344	377	374,5	469,5	533,5	550	565	582,5	656	648	633	623
I-sone 2	176	135	84	45	70	60	52	78	93	70	54	59	44	47
I-sone 3	36,5	21	18,5	12,5	18,5	17,5	18	16,5	19	25	23,5	23,5	25	20
I-sone 4	18,5	30	31	22	26	40	34,5	40	48	50,5	37	29	47,5	43
I-sone 5	1,5	0,5		3	2,5		1,5	1	2,5	2,5	9	16,5	5,5	12



Sandbakk Ø, Holmberg HC, Leirdal S, Ettema G. The Physiology of World Class Sprint Skiers*. *Scand J Med Sci Sports.* 2011 Dec;21(6):e9-16

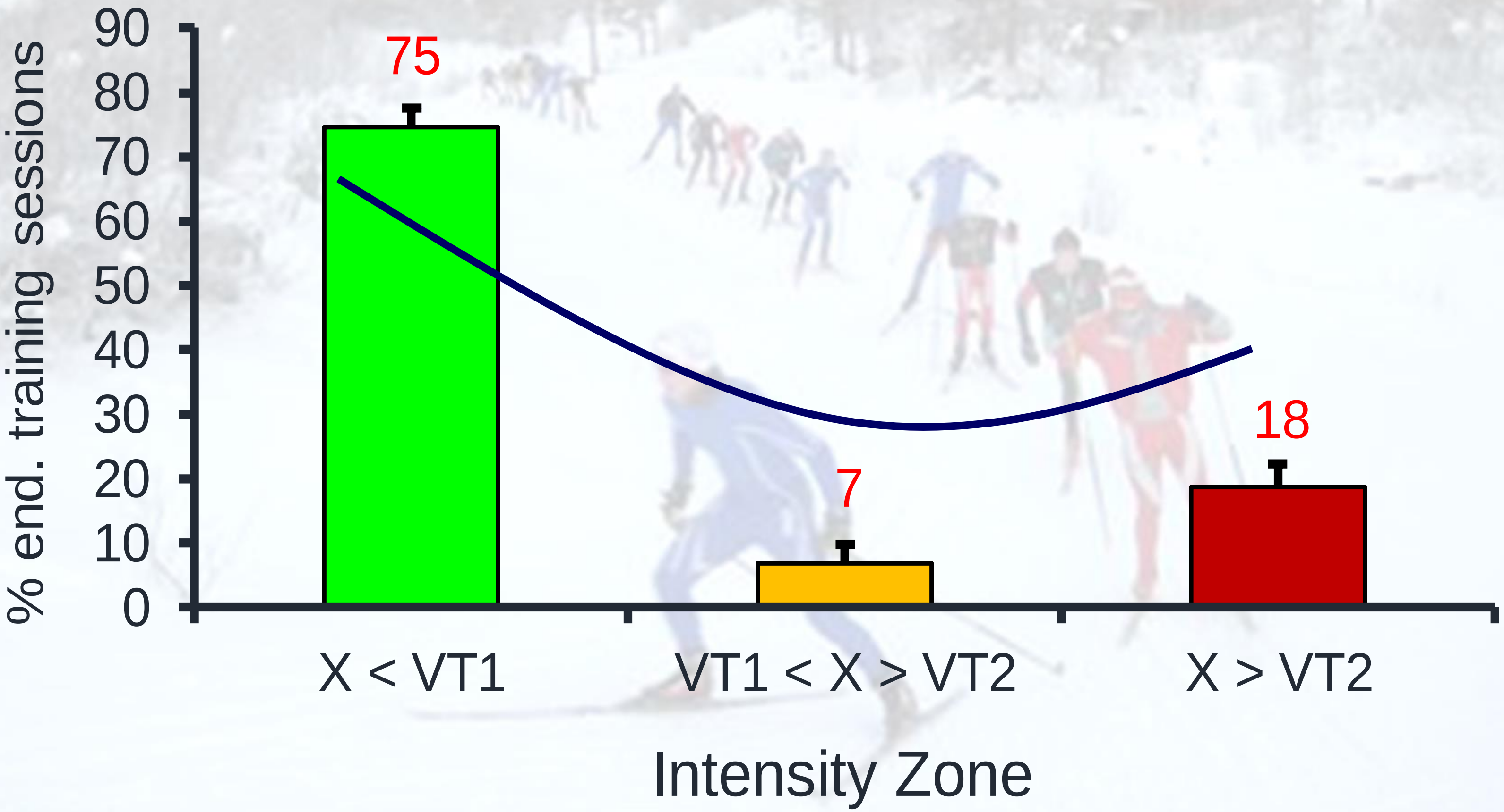
*The XC ski “sprint” event is actually a knockout race (4 rounds) with race durationof 2.5 - 3.5min each round.

	World-class ($n = 8$)		National level ($n = 8$)	
	Training hours	% of total training	Training hours	% of total training
LIT	340 ± 23**	76.4 ± 4.6	254 ± 94	73.1 ± 12.0
MIT	29 ± 12**	6.5 ± 2.2*	14 ± 6	4.4 ± 2.4
HIT	19 ± 3	4.4 ± 0.8	19 ± 8	5.6 ± 2.1
Speed	16 ± 7**	3.7 ± 1.5*	7 ± 3	2.3 ± 1.2
Strength	39 ± 14	8.8 ± 2.9	31 ± 14	9.4 ± 3.7
Total	445 ± 27**	100	341 ± 90	100

Main differences in training were that the world class skiers trained ~30% **more volume** (hours), and performed **more specific speed work**.

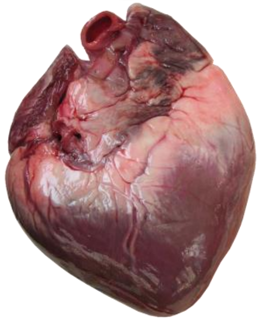
3. Training Intensity Zones are Signal/Stress balancing tools

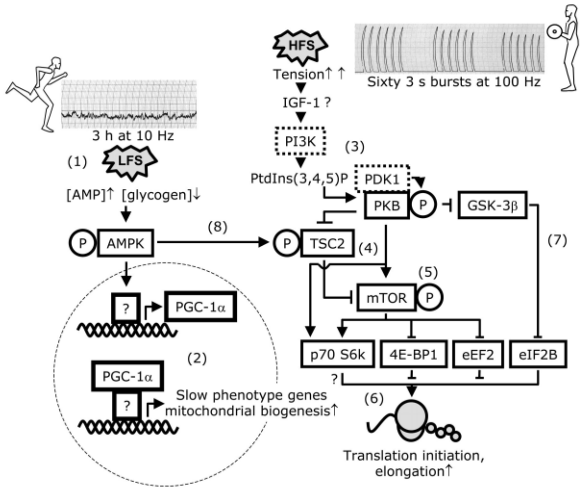
Seiler & Kjerland. Quantifying training distribution in elite endurance athletes: is there evidence of an optimal distribution? Scand. J. Med. Sci. Sports. 16, 49-56, 2006.



Glenn Kjerland

Endurance training is an *Optimization* problem!





Adaptive Stimulus

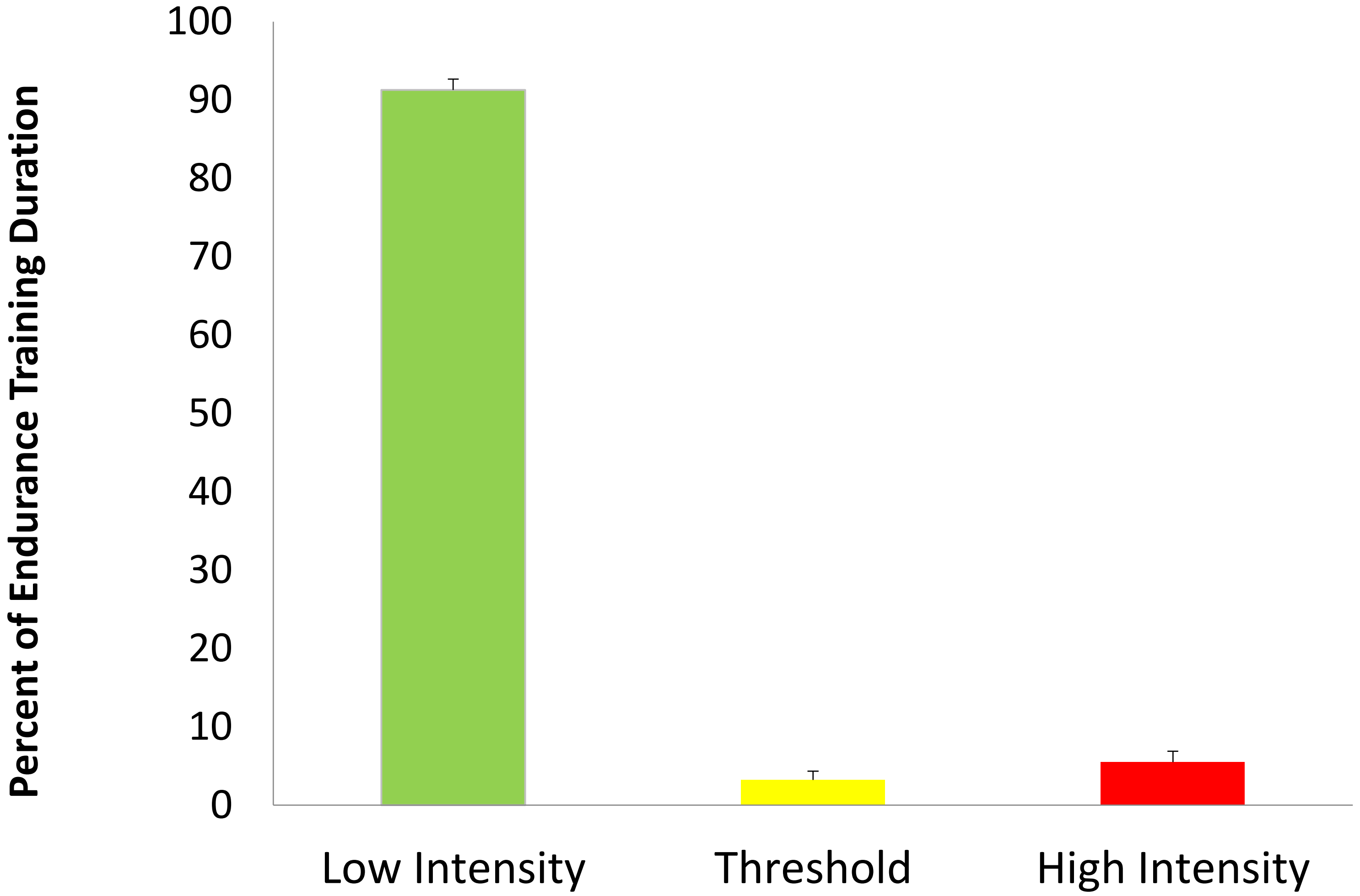
Stress

(Adjusting training characteristics)

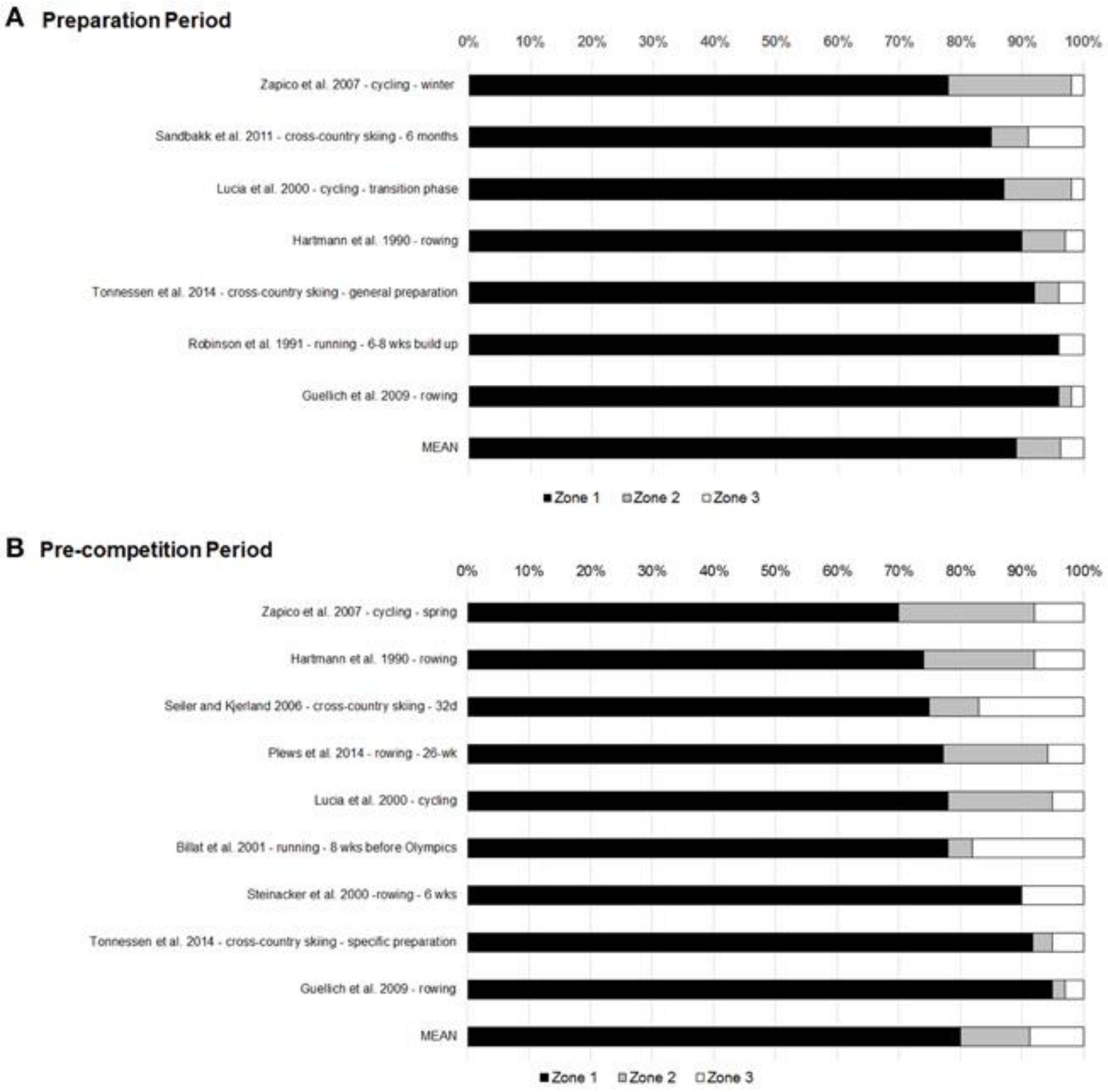
- Bone-tendon-muscle damage at cellular level
- Inflammation
- Repetitive sympathetic stress
- Immuno-suppression
- Psychological fatigue


"80-20 Intensity Distribution"
Protection against:
• Inertia
• Inexperience
• Ego
• Malfunctions

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



~80% LIT sessions is very consistently observed In studies of high performing endurance athletes…..BUT is the remaining 20%

Pyramidal or Polarized?

FOCUSED REVIEW ARTICLE
Front. Physiol., 27 October 2015 | http://dx.doi.org/10.3389/fphys.2015.00295

The training intensity distribution among well-trained and elite endurance athletes

Thomas L. Stöggl[1*] and Billy Sperlich[2]

Pyramidal or *Polarized*?

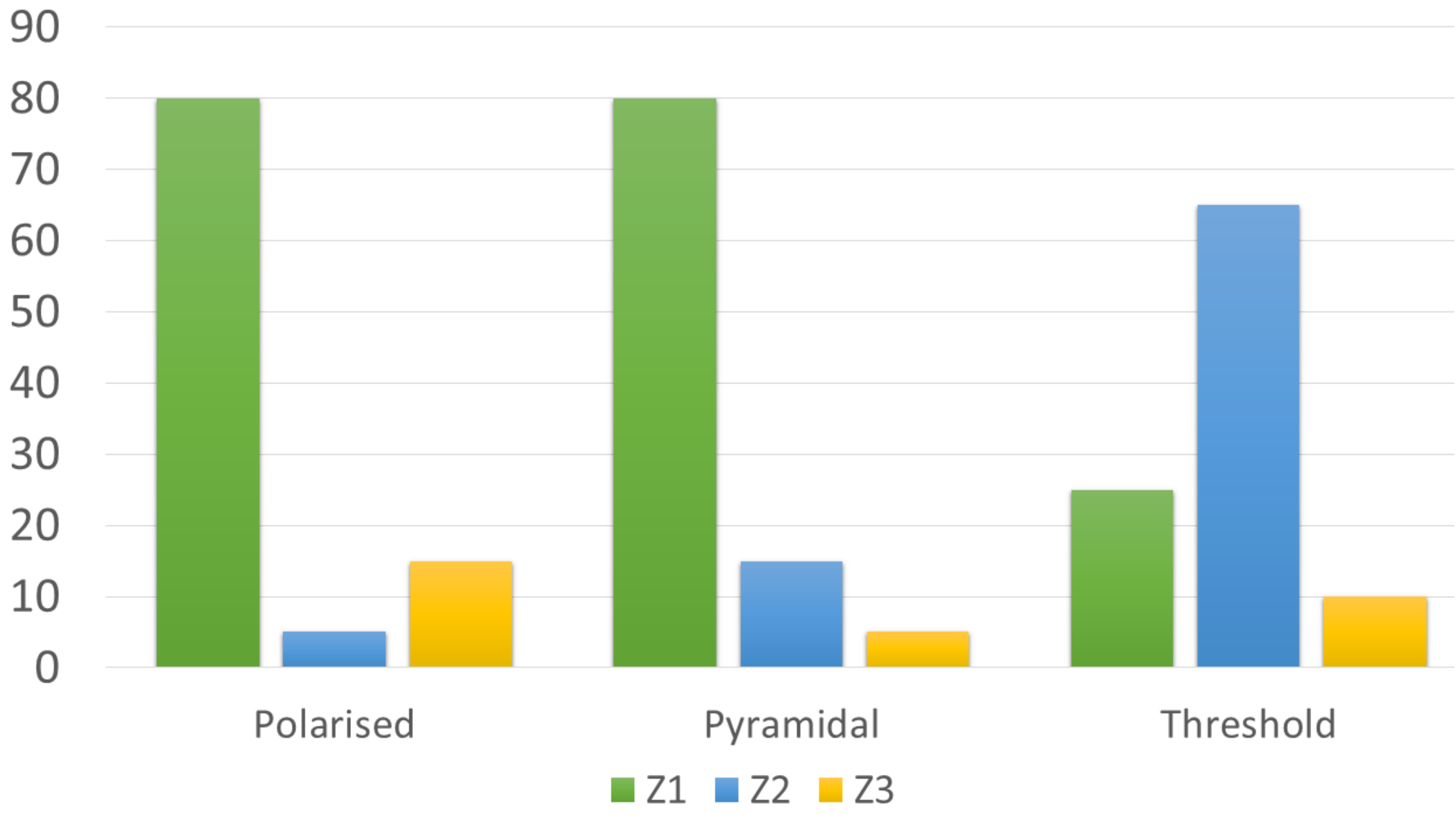


Figure from Chris Taylor https://www.espressocoaching.net/blog/archives/05-2020

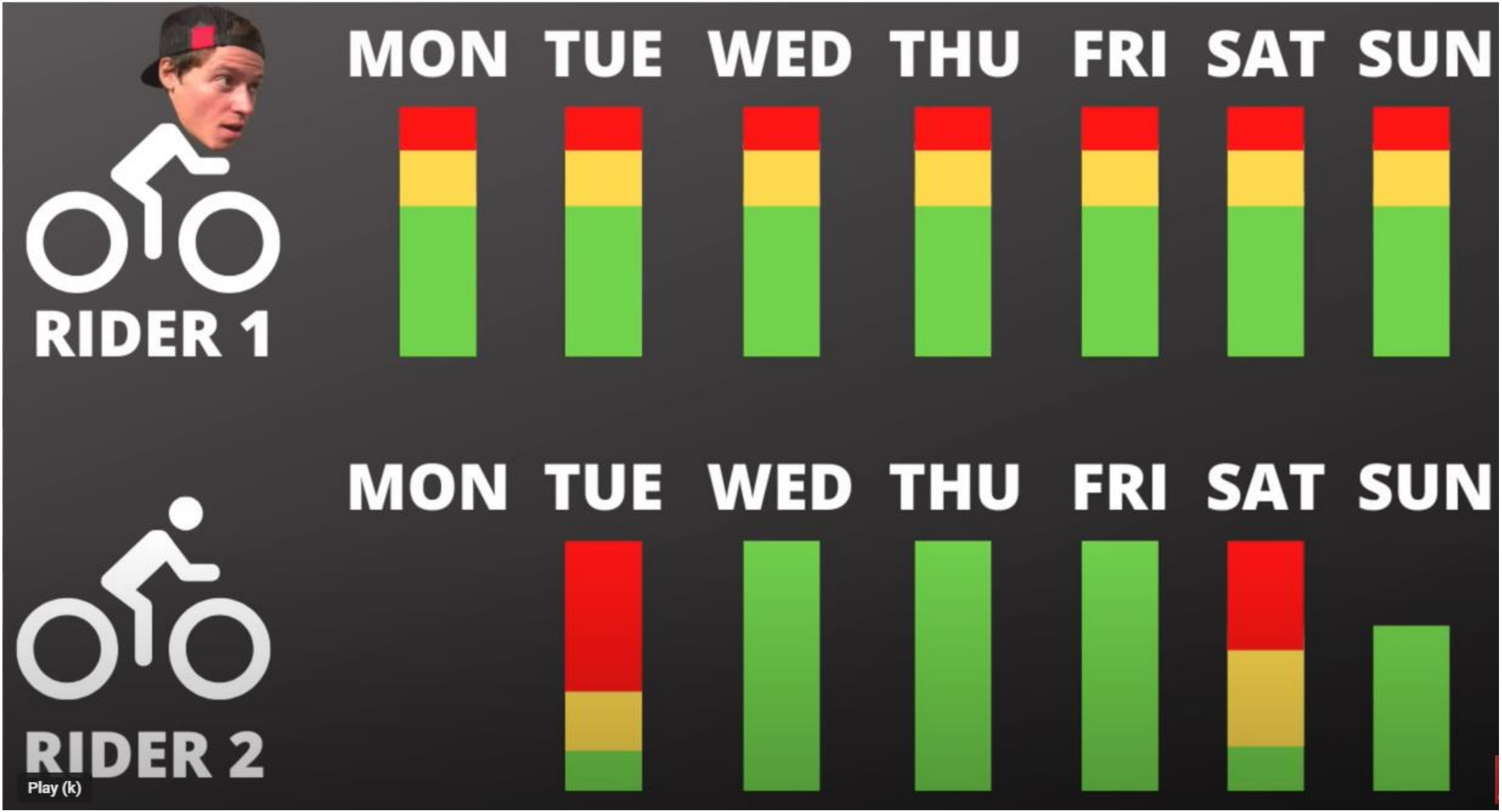
They share ~80% LIT **sessions** in common

"Threshold" sessions are high stress sessions!

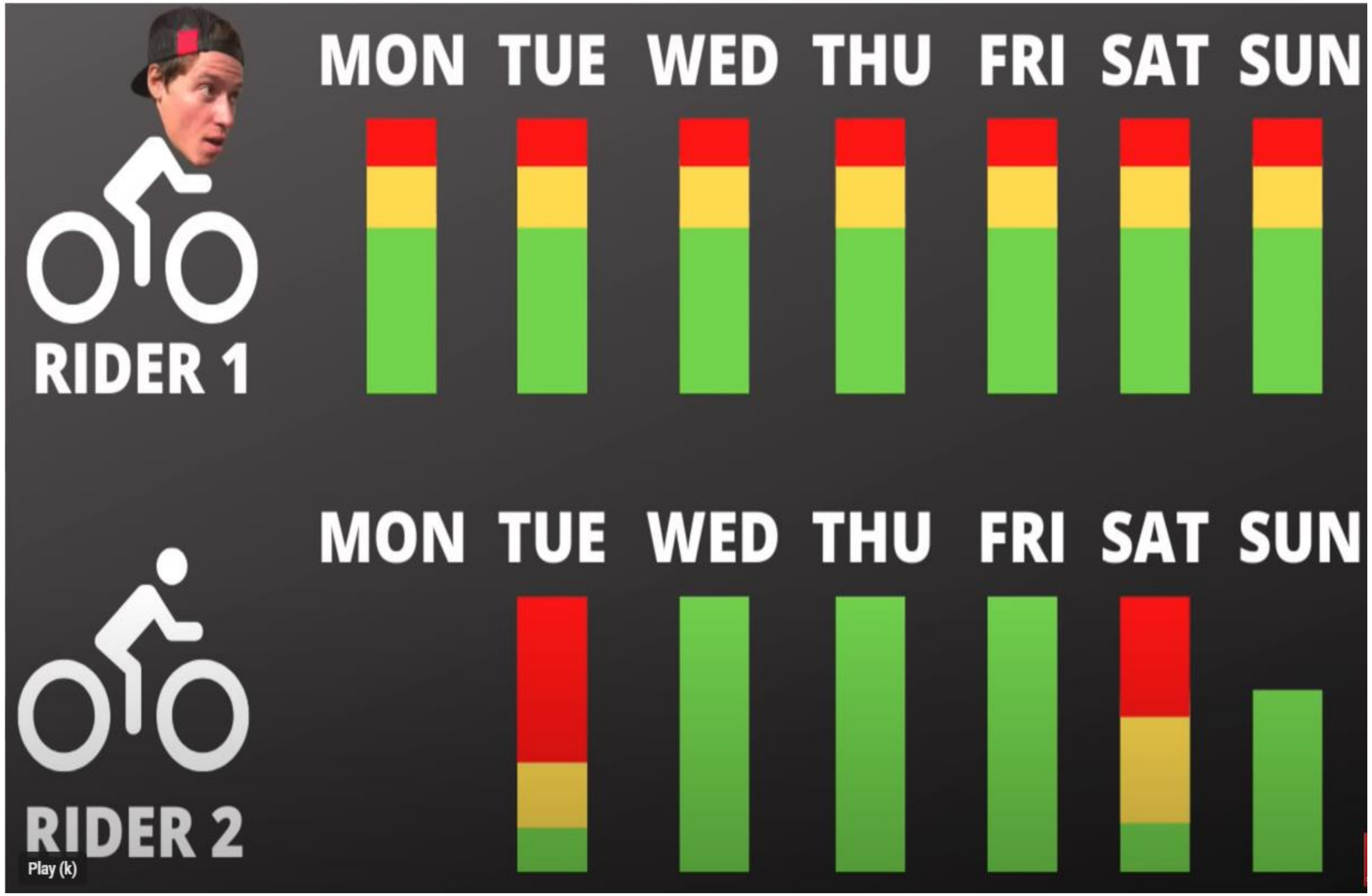
They are both used at different times of the season by many athletes

Polarized power/pace will often give **Pyramidal** HR distribution!

Of WHAT?



Screenshot from video by Dylan Johnsen: https://www.youtube.com/watch?v=oLsBXW3mTDI&t=603s

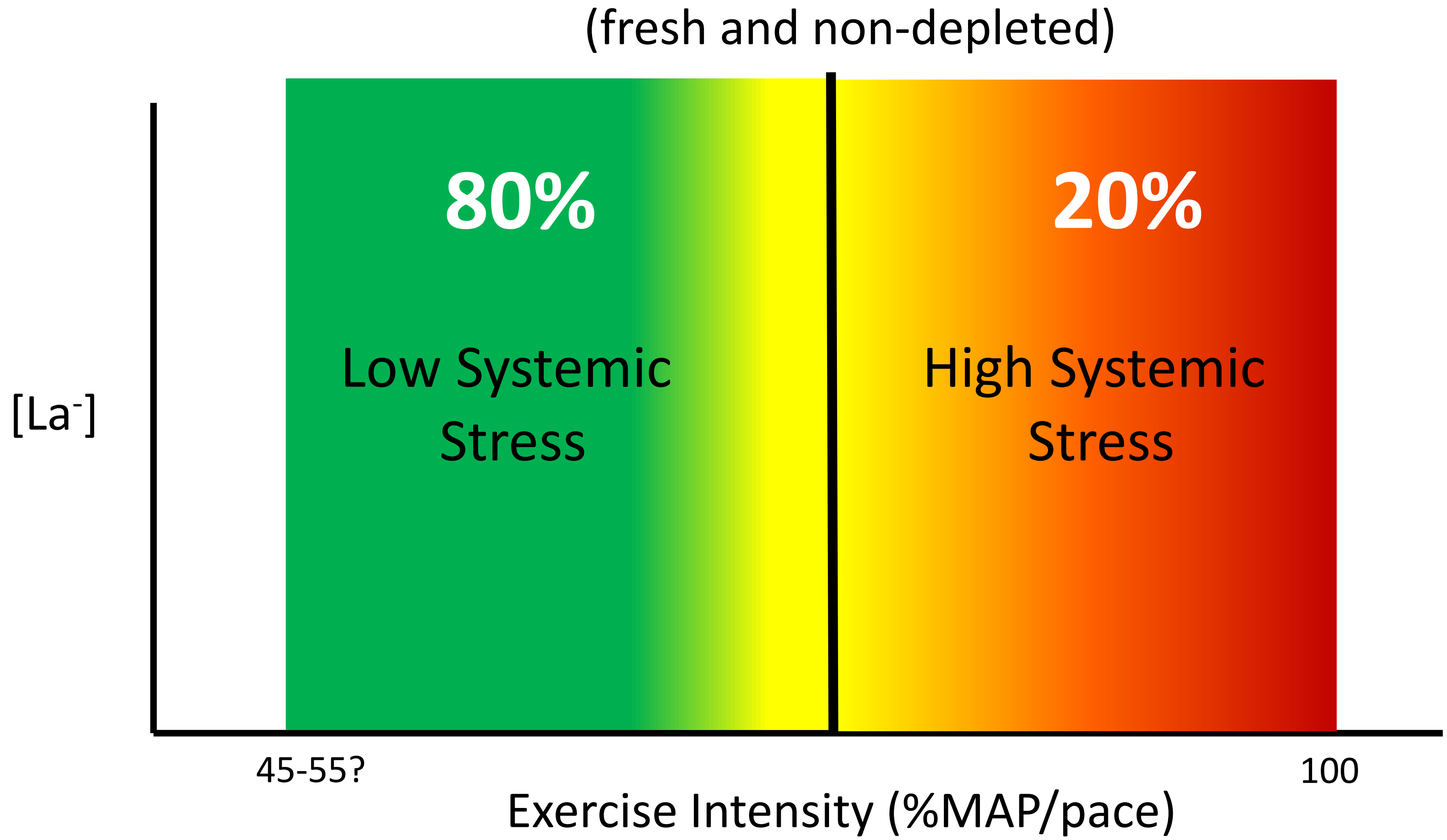


Screenshot from video by Dylan Johnsen:
https://www.youtube.com/watch?v=oLsBXW3mTDI&t=603s

Monotone stress load, stagnation and overreaching are likely

High Stress efforts concentrated in specific workouts with different intensity x duration combinations. Delayed recovery after hard sessions is “taken into account” in the training rhythm

2 "training stress zones" that are *dynamic*

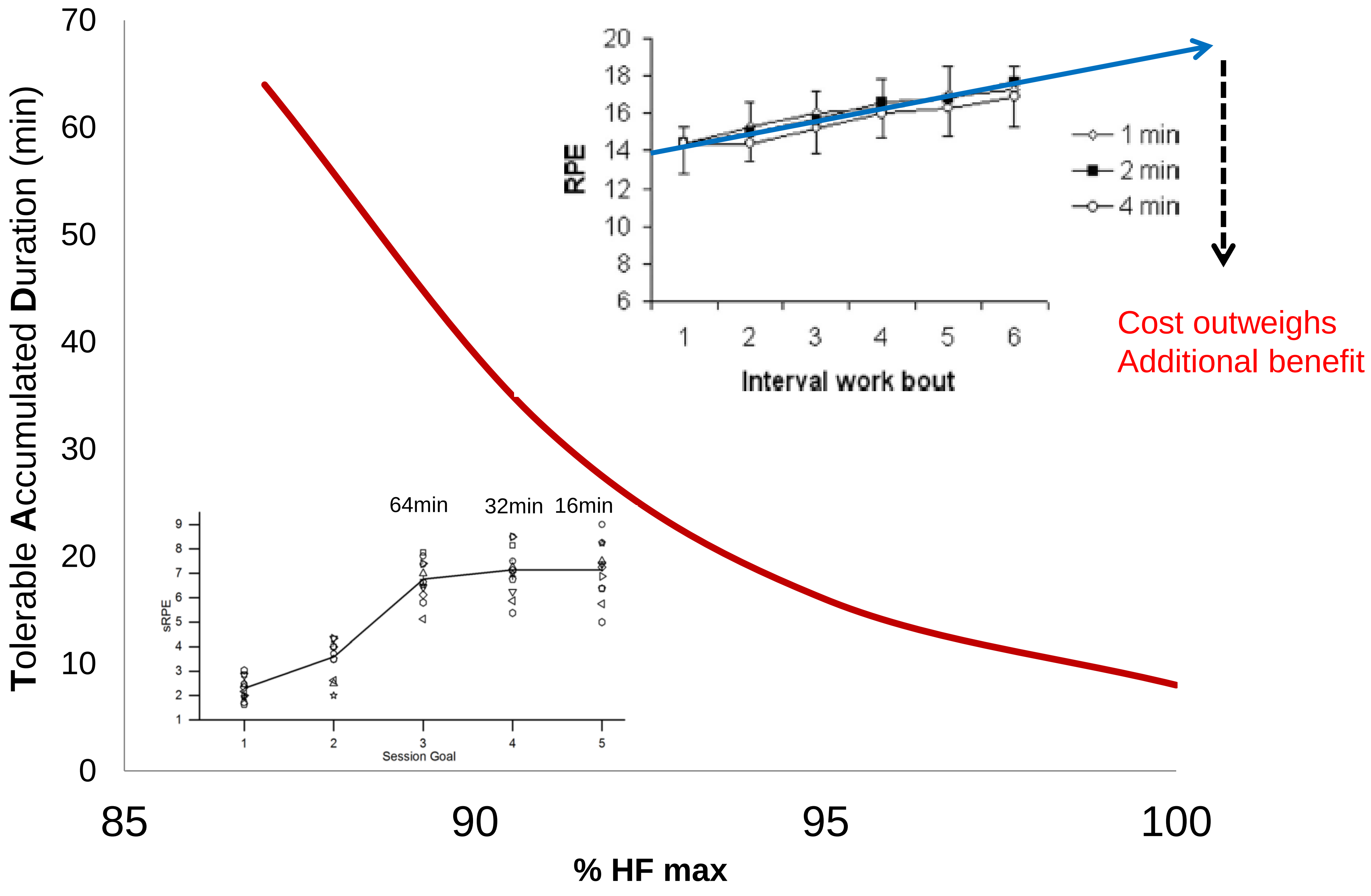


Low Stress - Short Recovery

High Stress - Longer Recovery

~80% of training sessions should land in this bucket

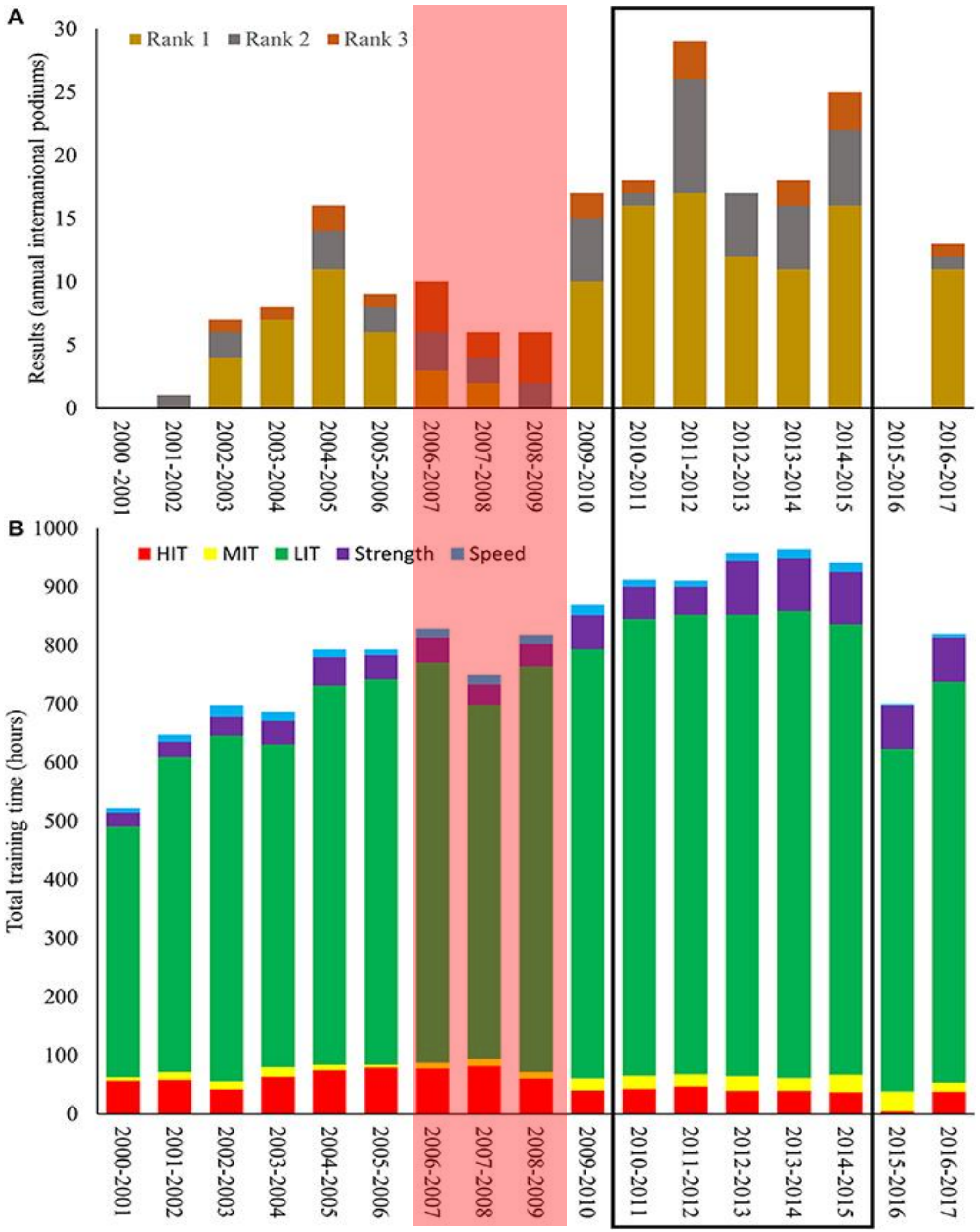
About 20% of sessions should be spread between these 2 buckets


Tolerable Accumulated Duration (min)
70
60
50
40
30
20
10
0
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
Cost outweighs
Additional benefit
64min
32min
16min
sRPE
9 8 7 6 5 4 3 2 1
1 2 3 4 5
Session Goal

Career Training Intensity Distribution (14 y, 8587 h)

Athlete: Bente Skari, NOR

Summary figure created based on training diary analysis by Espen Tønnessen, OLT NOR



ORIGINAL RESEARCH ARTICLE
Front. Physiol., 18 December 2017 | https://doi.org/10.3389/fphys.2017.01069

The Training Characteristics of the World's Most Successful Female Cross-Country Skier

Guro S. Solli[1], Espen Tønnessen[2] and Øyvind Sandbakk[3*]

[1]Department of Sports Science and Physical Education, Nord University, Bodø, Norway
[2]The Norwegian Olympic Federation, Oslo, Norway
[3]Department of Neuromedicine and Movement Science, Centre for Elite Sports Research, Norwegian University of Science and Technology, Trondheim, Norway

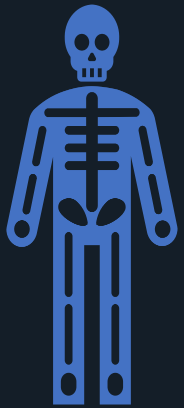
4. Triangulation also helps us know where we are in training

How do you feel?

How are you responding to the training?

Should we make adjustments?

The Endurance Training Monitoring Trinity



Power/Pace

Physiological Responses

Internal "Cost"

External Work

Perceived Effort/ Exertion

6	No exertion
7	
8	
9	
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	
20	Maximal exertion

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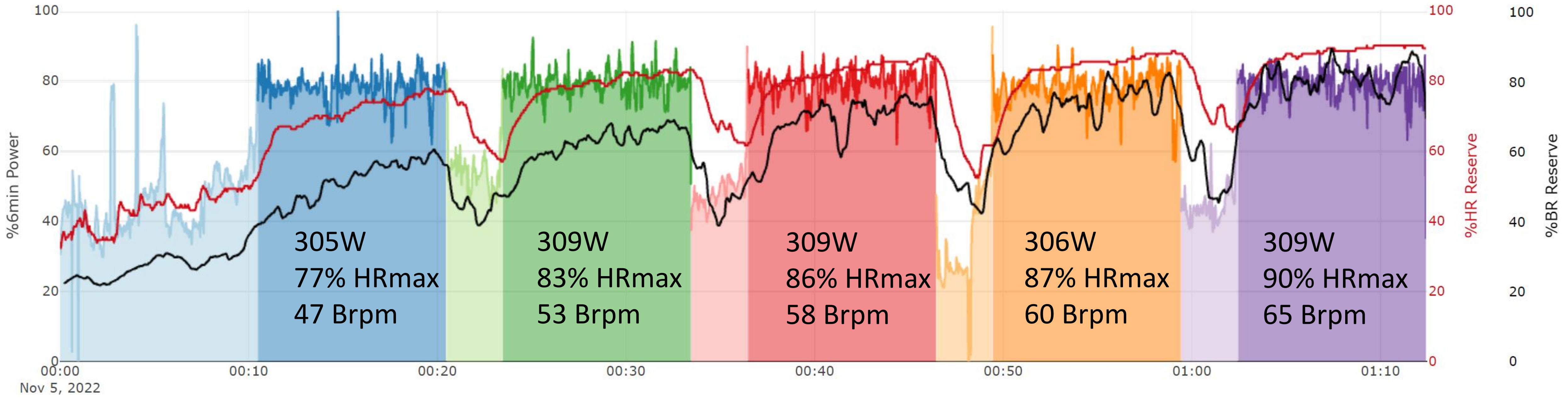
Anatomy of a *hard threshold session*: 5 x 10min, 3 min active recovery

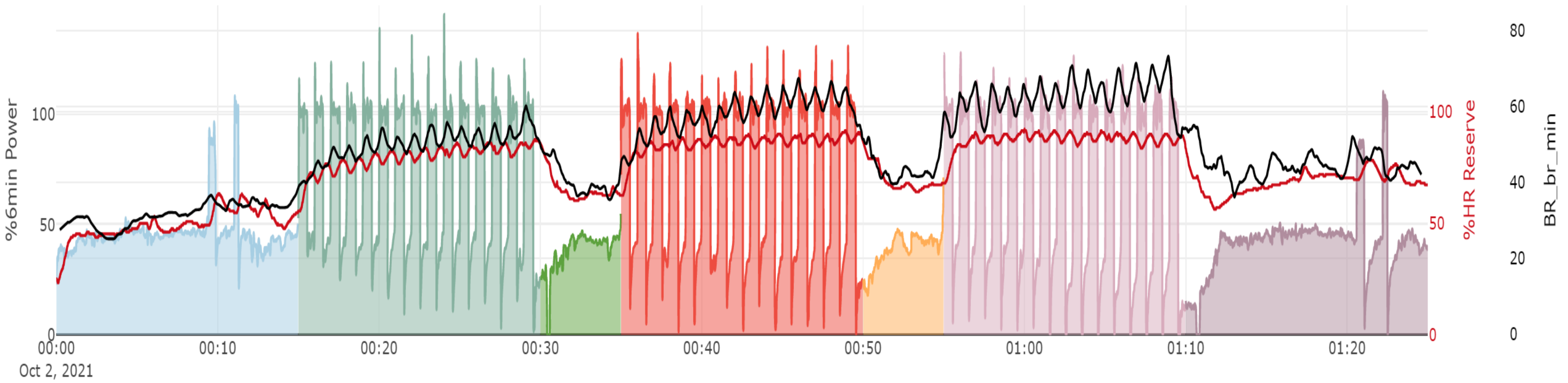


--------- RED Line = HR

---------BLACK line = Breathing Frequency

Data analyzed using Endura.fit
John Peters & Stephen Seiler

3 x 15min x 30:30s



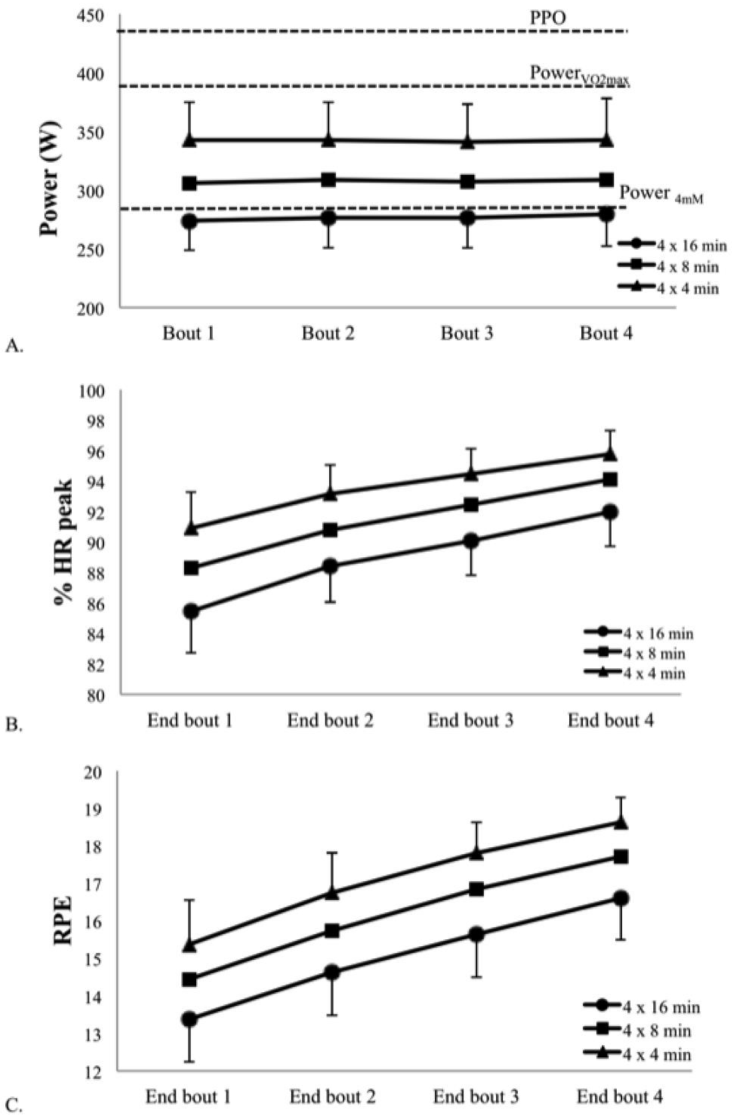
Internal "Cost"

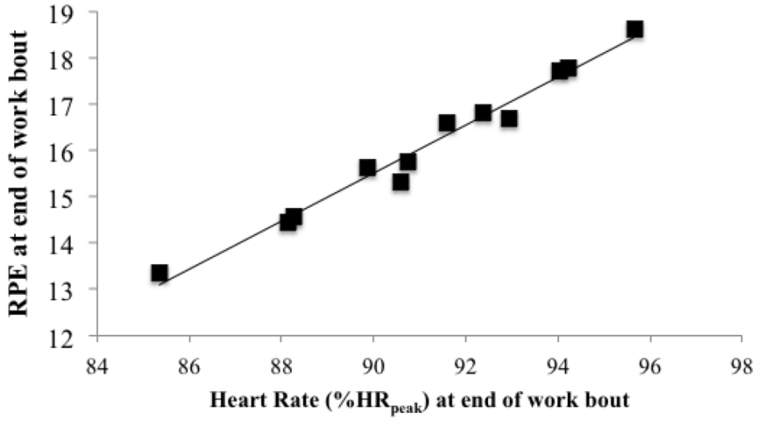
External Work

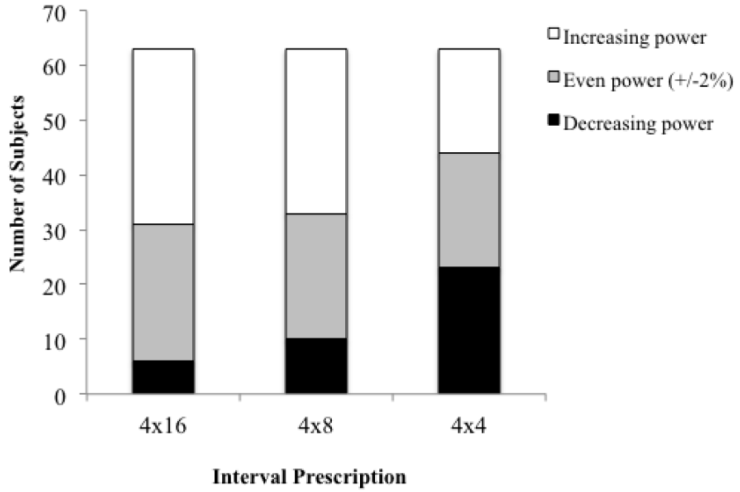
Increases with duration in all types of workouts: quite slowly <LT1, much faster >LT1 and very fast >LT2

Perceptual measures and Effort Matching

6	Total rest
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	MAXIMAL effort







International Journal of Sports Physiology and Performance, 2017, 12, S2-80-S2-86
http://dx.doi.org/10.1123/ijspp.2016-0464

Human Kinetics
ORIGINAL INVESTIGATION

How Does Interval-Training Prescription Affect Physiological and Perceptual Responses?

Stephen Seiler and Øystein Sylta

Effort ≈ Exertion magnitude x Exertion duration

“Exertion”, as measured by RPE seems to be intensity oriented. So, low intensity (LIT) and Threshold sessions will not drive a maximal exertion, even when highly fatigued. The body goes “empty” and prevents maximal exertion. However, the “effort “ in these sessions can be maximal, but the perceptions are different (empty legs versus being “full of lactic acid”).

International Journal of Sports Physiology and Performance, 2017, 12, S2-80-S2-86
http://dx.doi.org/10.1123/ijspp.2016-0464

Human Kinetics
ORIGINAL INVESTIGATION

How Does Interval-Training Prescription Affect Physiological and Perceptual Responses?

Stephen Seiler and Øystein Sylta

RPE

kilojoules

CTL

Training Hours

Strain

Monotony

ATL

Stress

TRIMPS

TSS

hrTSS

Load

Session RPE

Watts

sRPE

Training kilometers

UiA

UiA | The co-creation university

ACCUMULATED side-effects

Strain

(24h+ post training)

- Mood state change
- Decreased Readiness to Train
- Large HR/load Shift (up or down)
- Decreased Peak Blood La-
- Peak 6s power/CMJ decline
- Decreased resting HRV
- Decreased testosterone response
- Decreased cortisol response

ACUTE Responses

Stress

- RPE/HR/Ventilation shift at same power/pace
- Efficiency deterioration (technique collapse)
- Greater pace variation
- Increased cortisol release (saliva or blood)
- Increased/altered muscle activation at same power or pace

Load

NEUTRAL: Different combinations of intensity x duration can give same load!

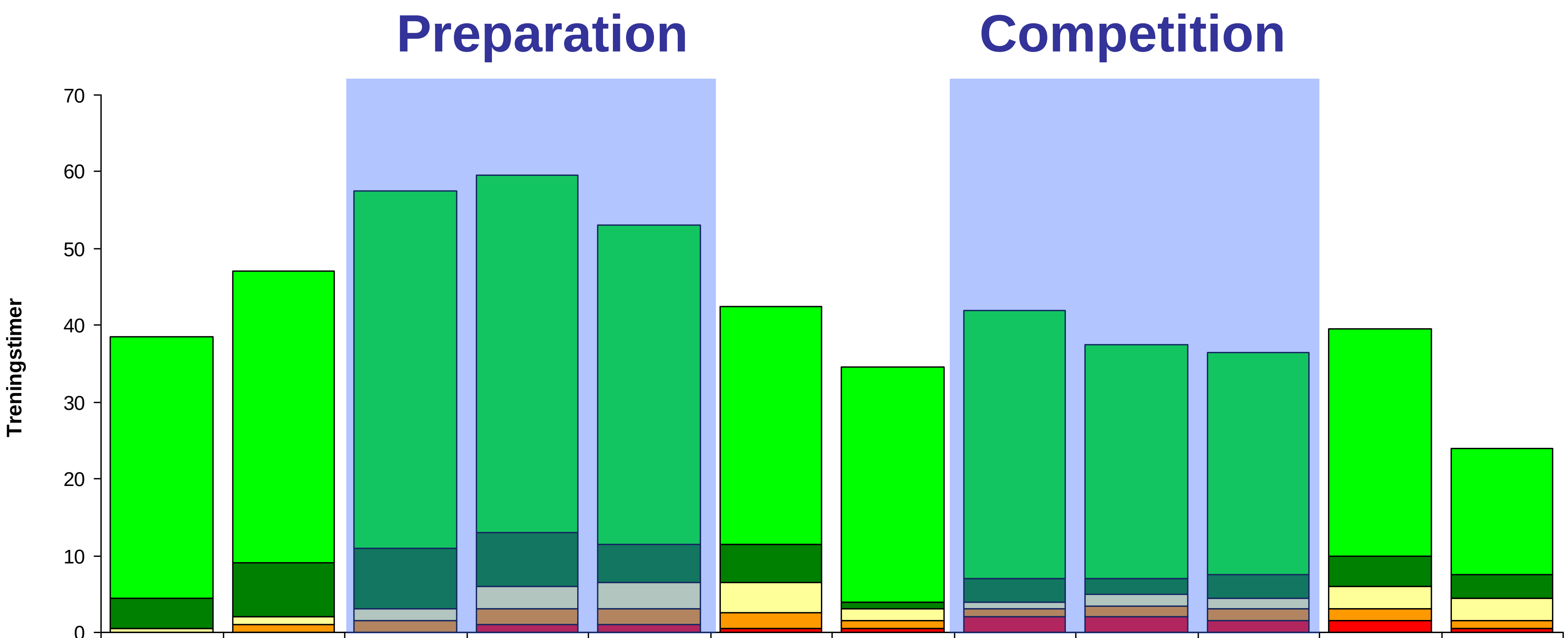

@StephenSeiler

Some extra figures for Q&A

Ingrid Kristiansen
5 World Records
World Champion

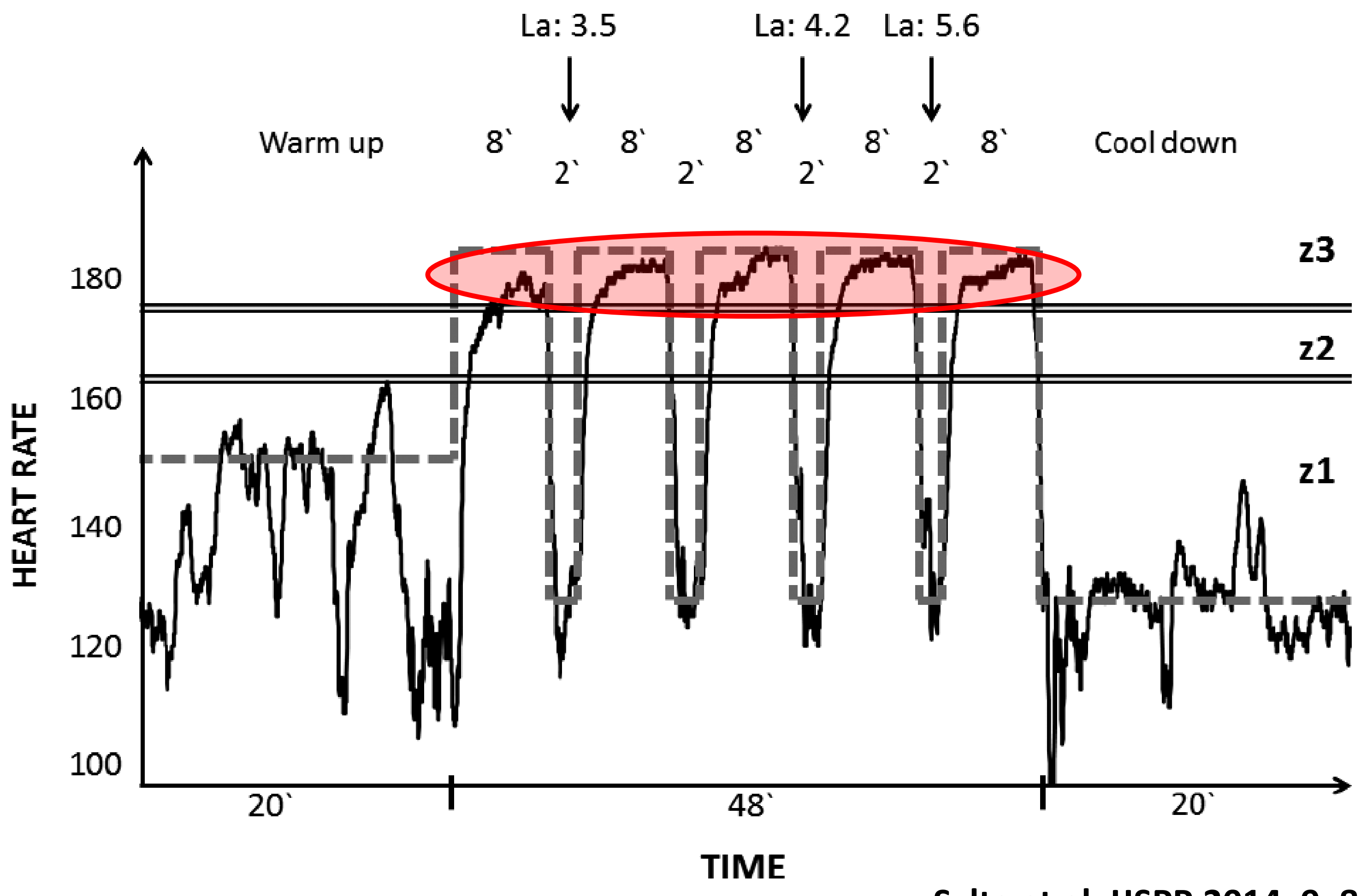
Data from Espen Tønnesen
Olympiatoppen with permission

Preparation Competition

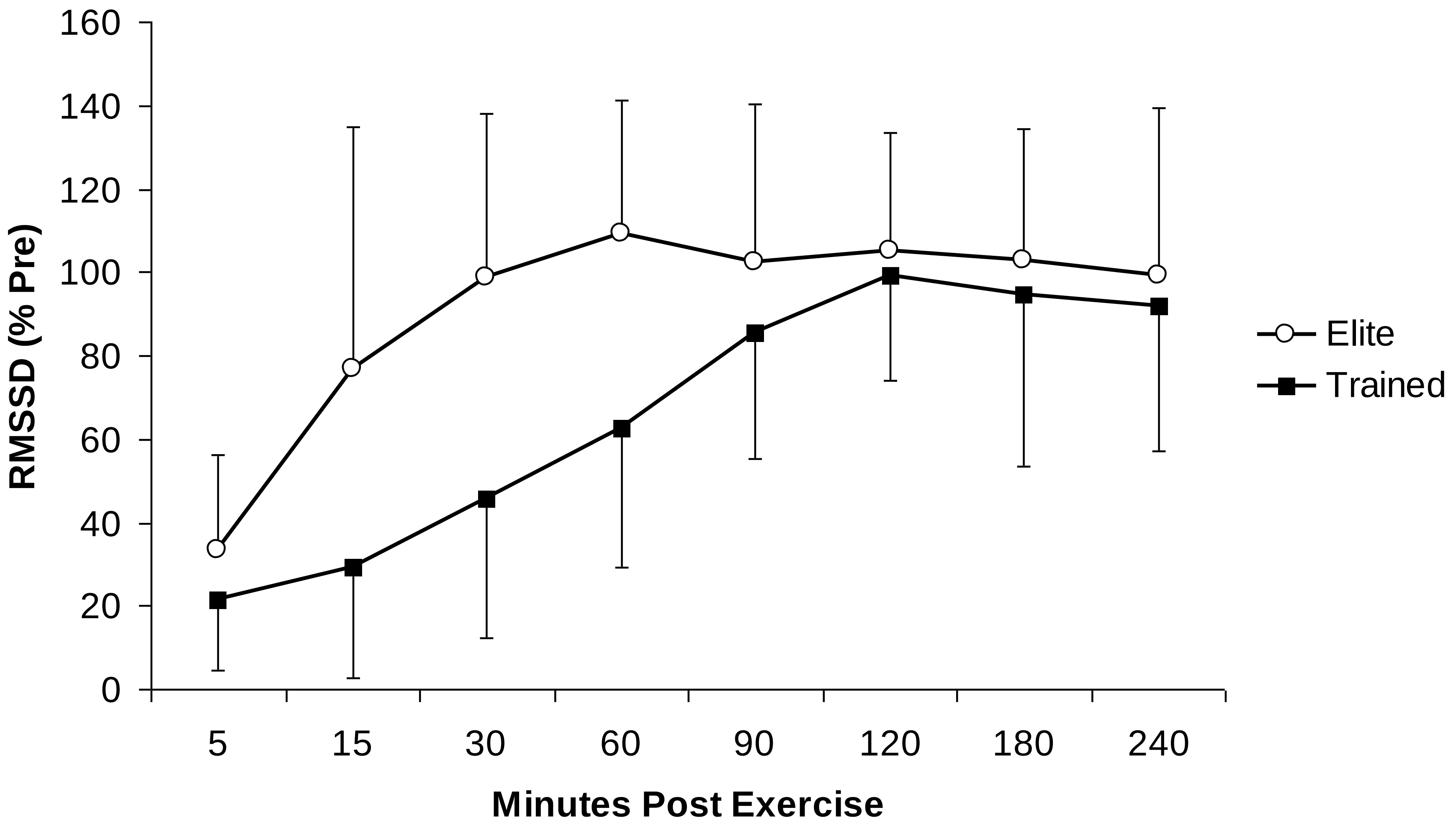


	November	Desember	Januar	Februar	Mars	April	Mai	Juni	Juli	August	September	Oktober
I-sone 1	34,00	38,00	46,50	46,50	41,50	31,00	30,50	35,00	30,50	29,00	29,50	16,50
I-sone 2	4,00	7,00	8,00	7,00	5,00	5,00	1,00	3,00	2,00	3,00	4,00	3,00
I-sone 3	0,50	1,00	1,50	3,00	3,50	4,00	1,50	1,00	1,50	1,50	3,00	3,00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

1. Time-in-Zone (underreports true high-intensity time)
2. Modified TIZ (adjusts for this)
3. Session Goal (assigns each session to an intensity category)



Sylta et al. IJSPP 2014, 9, 85 -92.



Autonomic recovery from identical Interval sessions in **highly trained** versus **trained** endurance subjects

Seiler, Haugen, and Kuffel. Autonomic recovery after exercise in trained athletes: intensity and duration effects. *Med. Sci. Sports Exerc.* 39 (8):1366-1373, 2007.

Table 1 Characteristics of the Subject

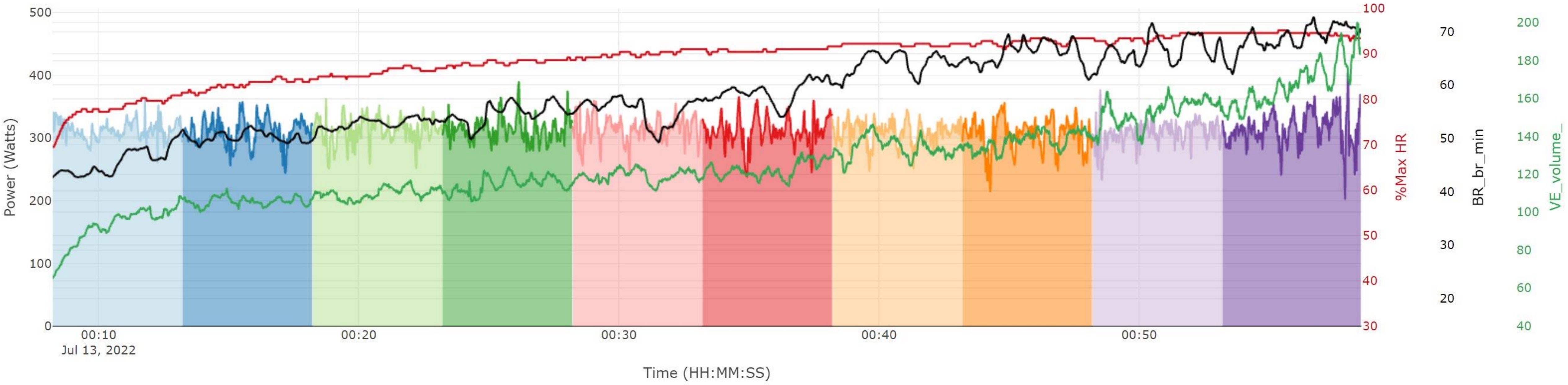
Variables	Men		Women	
	Running (n = 44)	Cycling (n = 47)	Running (n = 32)	Cycling (n = 37)
Age, y	23 (4)	20 (3)	21 (2)	25 (6)
Weight, kg	74 (7)	74 (7)	59 (4)	60 (6)
Height, cm	181 (6)	183 (5)	168 (4)	167 (6)
VO_2max, $mL \cdot kg^{-1} \cdot min^{-1}$	77.1 (5.4)	77.7 (6.0)	64.9 (3.9)	63.1 (5.6)
HR_{peak}, $beats \cdot min^{-1}$	193 (6)	195 (7)	193 (7)	191 (9)

Abbreviations: HR_{peak}, peak heart rate during the maximal oxygen uptake test; VO_2max, maximal oxygen uptake. Note: Data are presented as mean (SD).

Losnegard, T. J., Skarli, S., Hansen, J., Roterud, S., Svendsen, I. S., Rønnestad, B., Paulsen, G. (2021). Is Rating of Perceived Exertion a Valuable Tool for Monitoring Exercise Intensity During Steady-State Conditions in Elite Endurance Athletes? **International Journal of Sports Physiology and Performance (IJSPP), 16(11), 1589-1595.**

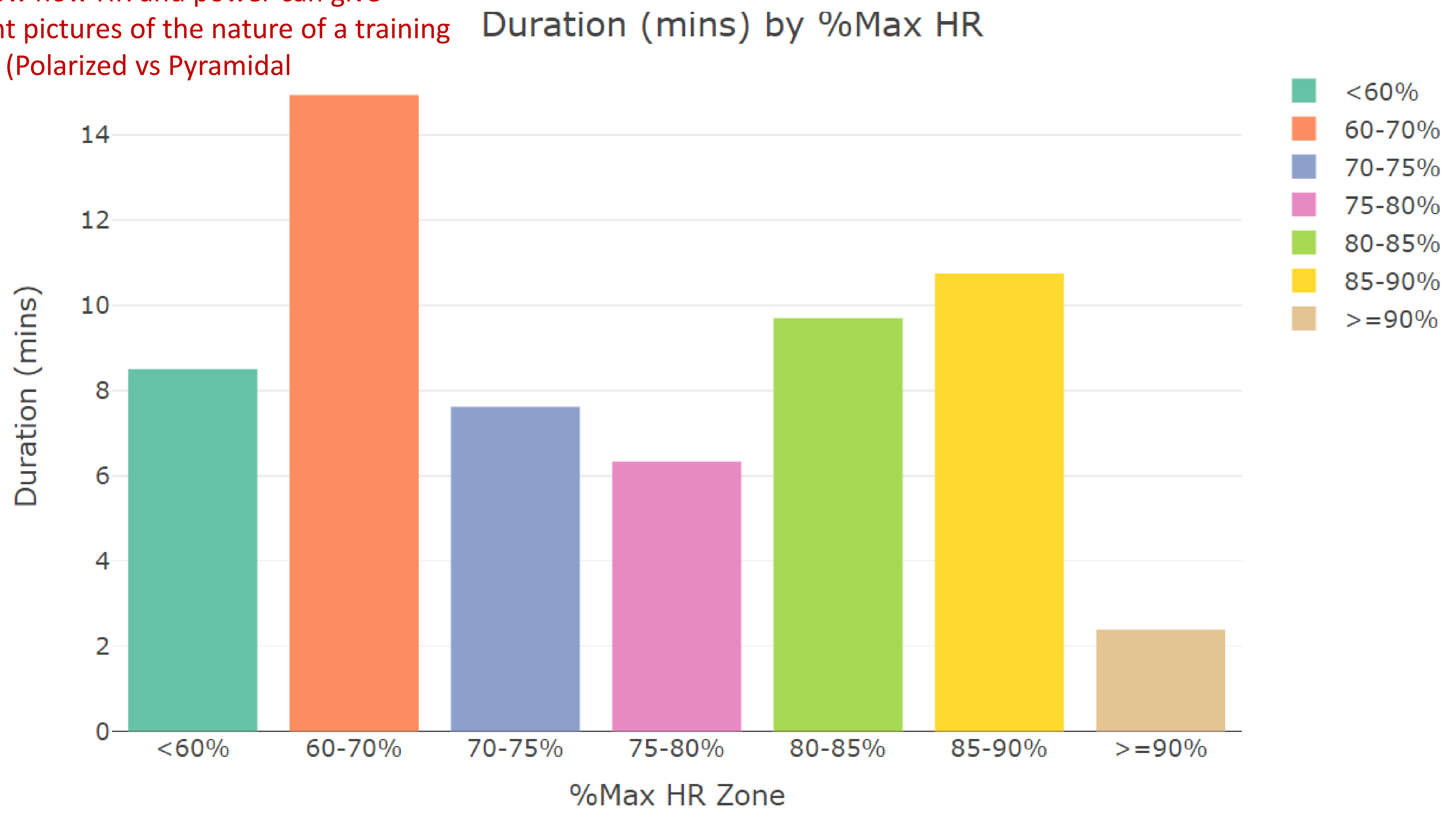
Table 2 Reported RPE and Associated Physiological Variables

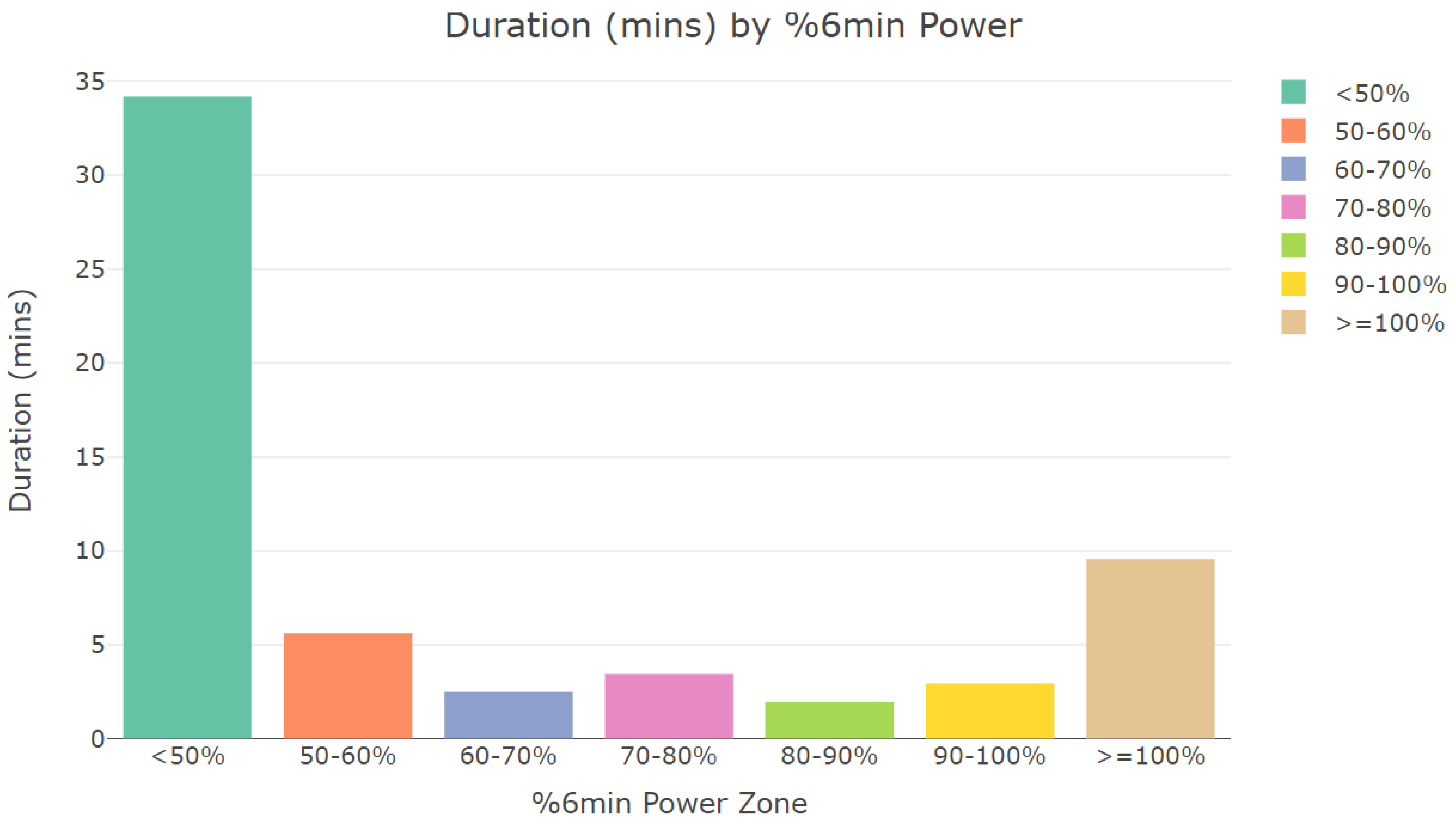
RPE (6–20)	Description	HR, % of HR_{peak}	VO_2, % of VO_2max	$[La^-]$, $mmol \cdot L^{-1}$
6		—	—	—
7	Very, very light	—	—	—
8		68 (7)	53 (9)	1.1 (0.3)
9	Very light	71 (7)	56 (8)	1.1 (0.3)
10		73 (6)	58 (9)	1.1 (0.3)
11	Fairly light	74 (7)	61 (7)	1.1 (0.3)
12		78 (6)	66 (8)	1.4 (0.5)
13	Somewhat hard	81 (6)	70 (7)	1.7 (0.6)
14		86 (6)	75 (8)	2.5 (0.9)
15	Hard	88 (5)	80 (7)	3.3 (1.2)
16		91 (5)	84 (6)	4.2 (1.3)
17	Very hard	93 (5)	86 (4)	4.5 (1.3)
18		—	—	—
19	Very, very hard	—	—	—
20		—	—	—

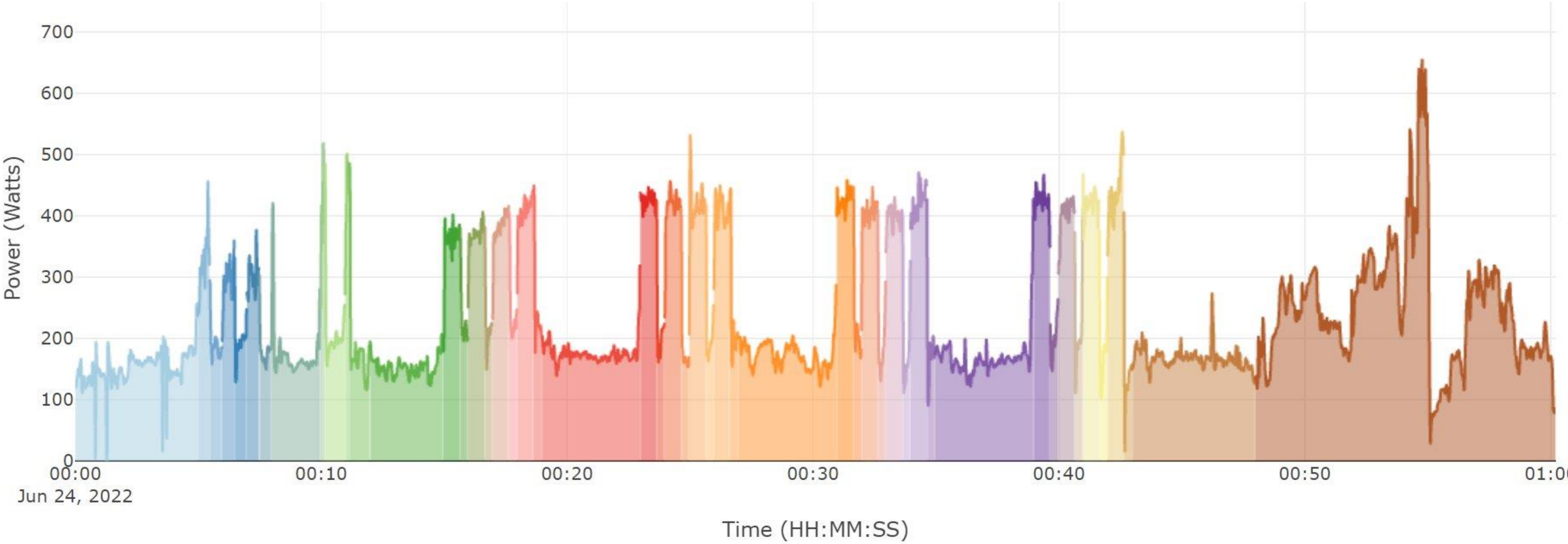


Power (Watts)
500
400
300
200
100
0
00:10
Jul 13, 2022
00:20
00:30
00:40
00:50
Time (HH:MM:SS)
%Max HR
100
90
80
70
60
50
40
30
BR_br_min
70
60
50
40
30
20
VE_volume_
200
180
160
140
120
100
80
60
40

Slides 60-62 are the same workout and show how HR and power can give different pictures of the nature of a training session (Polarized vs Pyramidal




Duration (mins) by %6min Power
Duration (mins)
35
30
25
20
15
10
5
0
<50%
50-60%
60-70%
70-80%
80-90%
90-100%
>=100%
%6min Power Zone
<50%
50-60%
60-70%
70-80%
80-90%
90-100%
>=100%


700
600
500
400
300
200
100
0
Power (Watts)
00:00
Jun 24, 2022
00:10
00:20
00:30
00:40
00:50
01:00
Time (HH:MM:SS)