Load, Stress, Strain:

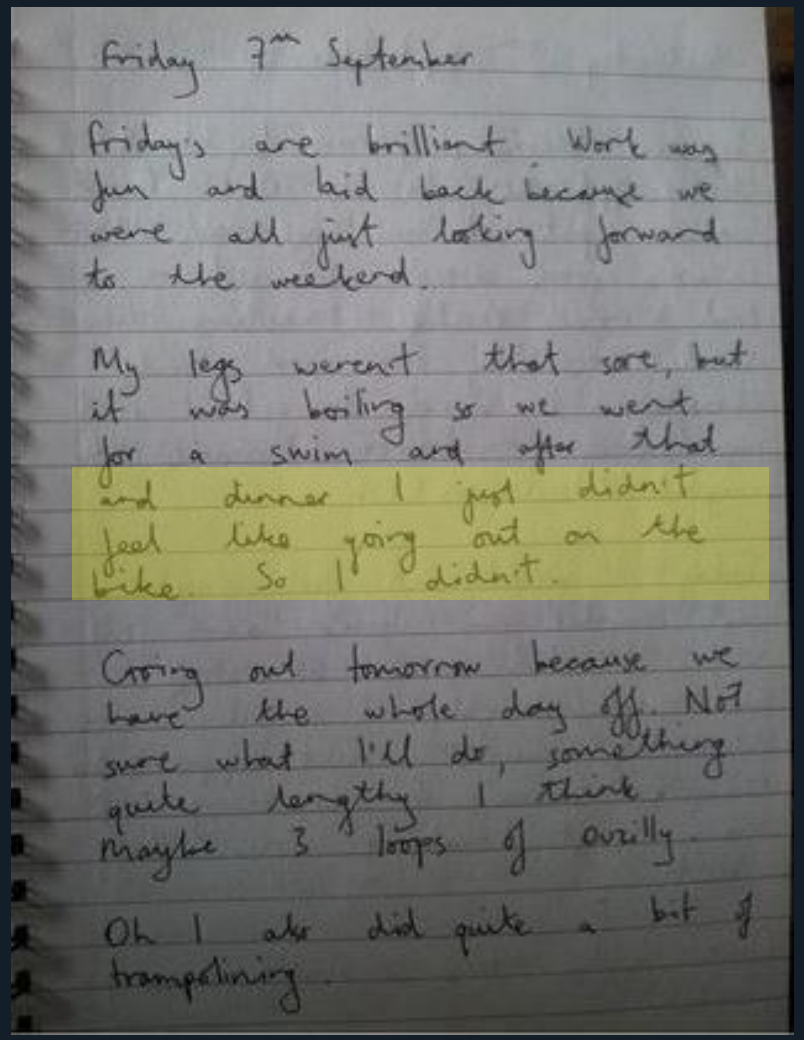
Repurposing an established framework for long-term endurance development

Stephen Seiler PhD

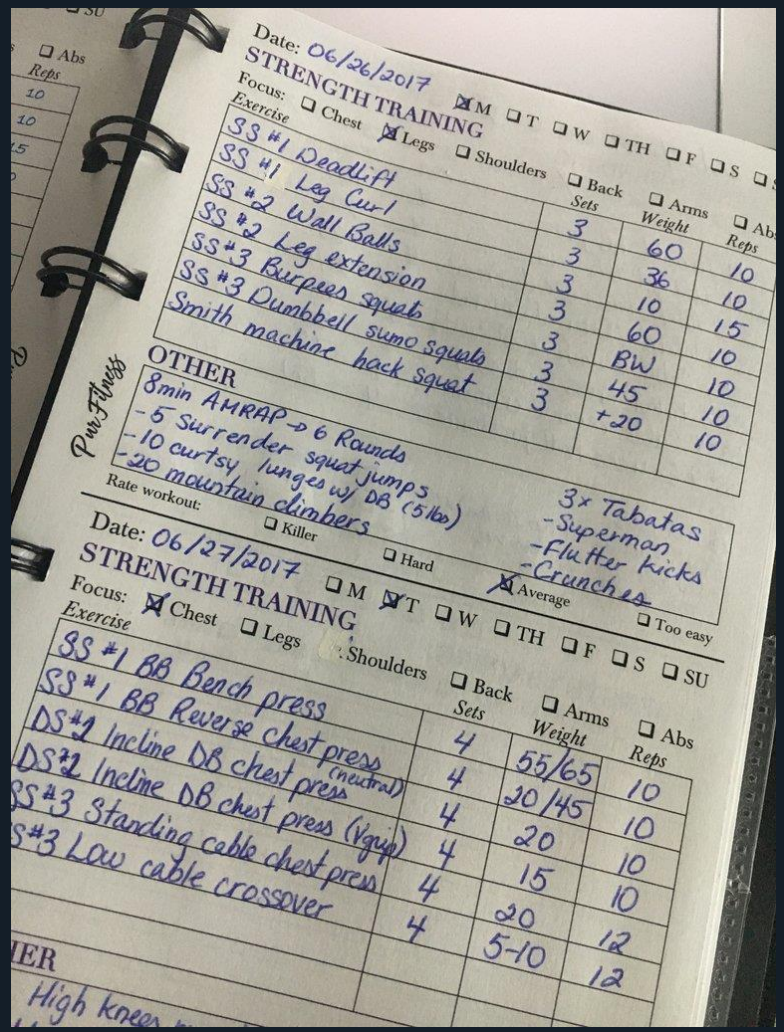
UiA | The co-creation university

Why do we measure/monitor?

1. Verify prescription execution- **prescription ≠ execution**!
2. Individualize & revise training prescription
3. Detect deviation and deterioration (early)- muscular fatigue, autonomic nervous system imbalance, endocrine function disruption
4. Quantify development & document the process

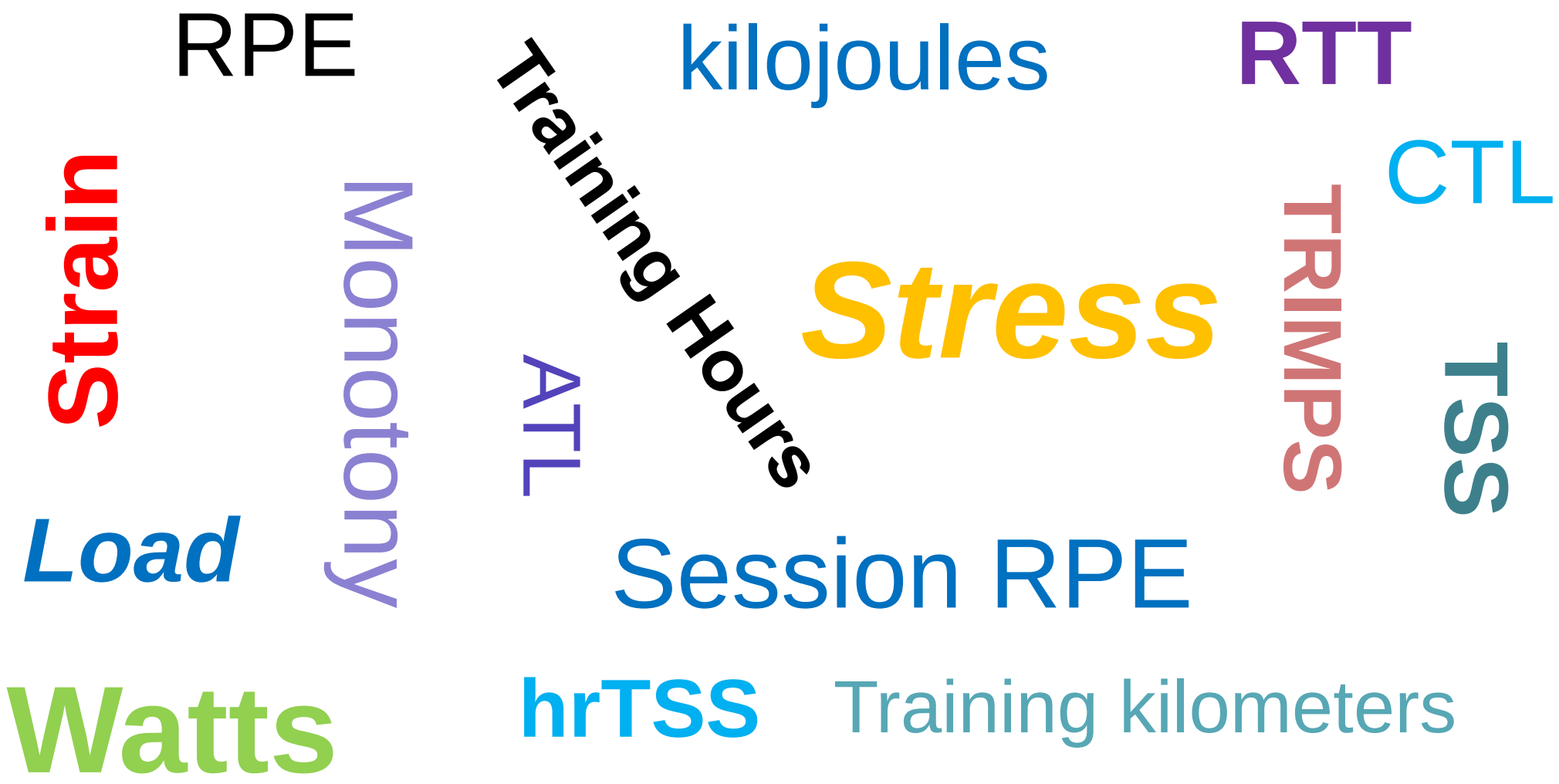


Diary of Training



Logbook

Digital Metrics & Algorithms


RPE
Training Hours
kilojoules
RTT
CTL
Strain
Monotony
Stress
TRIMPS
TSS
ATL
Load
Session RPE
Watts
hrTSS
Training kilometers


How do you feel?
How are you responding to your training?
Are adjustments warranted?

Training *Load*

versus

Training *Stress*

versus

Training *Strain*

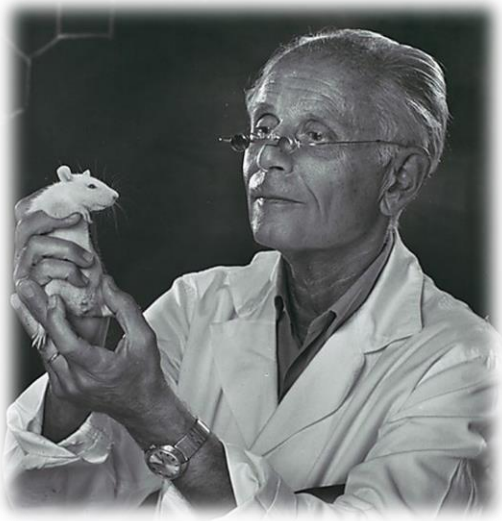
As a 19y old medical school student, Selye saw that patients with very different diseases had **similar general symptoms**…….

Hans Selye 1907-1982

- looking tired
- having no appetite
- losing weight
- preferring to lie down rather than stand
- not being in the mood to go to work

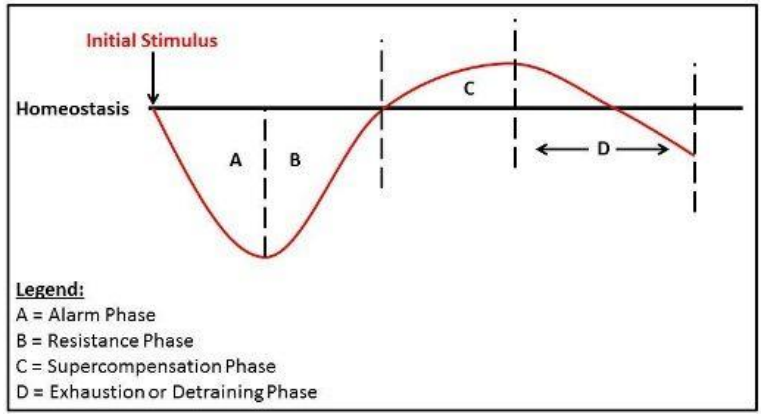
→ “***syndrome*** *of just being sick*”

The term "**stress**" was placed in the medical lexicon by **Hans Selye** in 1936…but he struggled for decades defining his own term.



Hans Selye 1907-1982

"*Stress* is **not** what happens to you, but how you react to it." (Selye 1974, 1977)

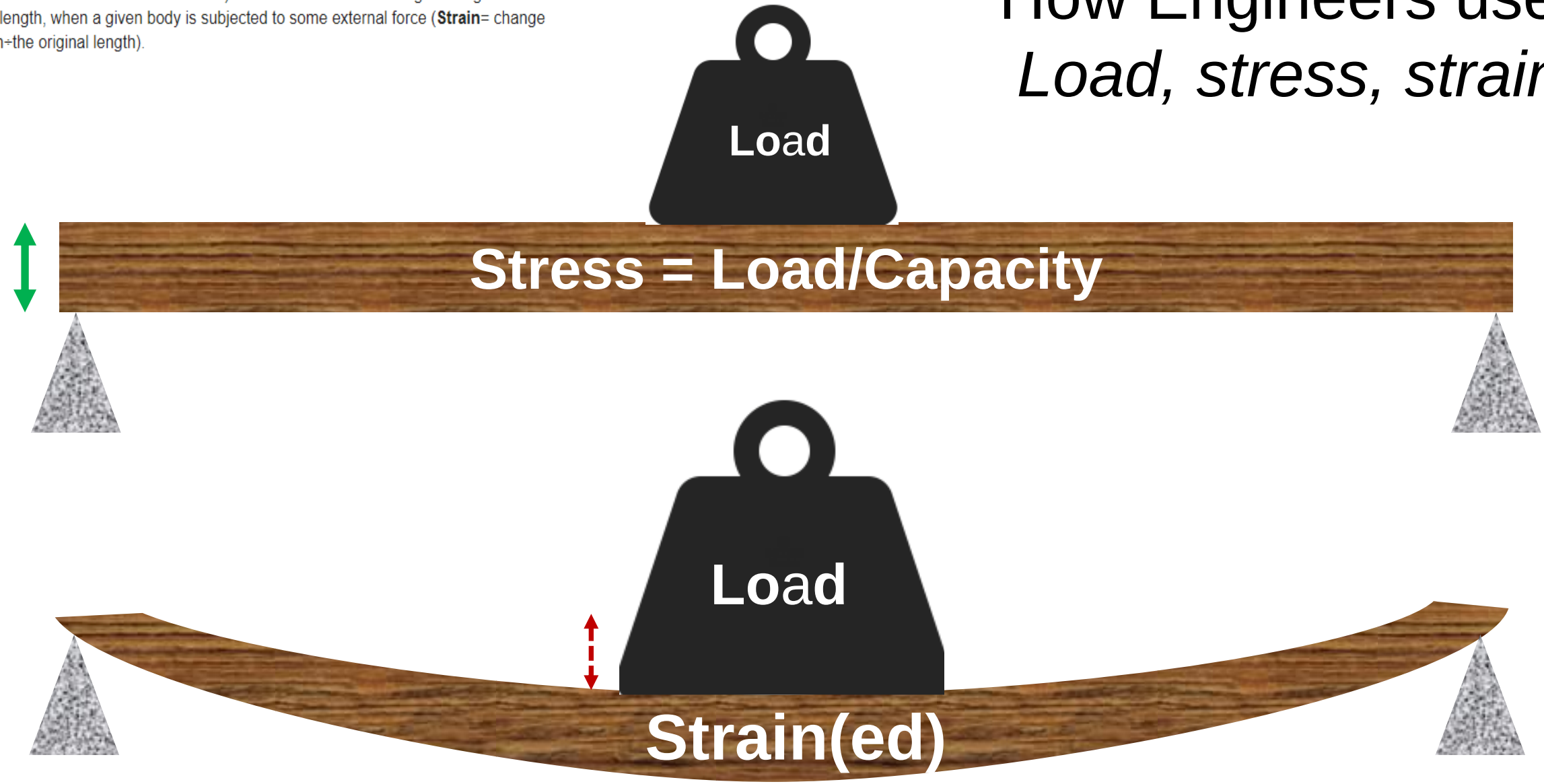


General Adaptation Syndrome (GAS)

Possibly unknown to Selye, physicists already used the term *stress* to describe the internal effect of a force or load placed on an object, potentially causing the object to bend, compress, or stretch. They call this resulting **deformation** STRAIN.

Stress is the ratio of force over area (S =F/A, where S is **stress**, F is the external force or **load** and A is the cross-sectional area). **Strain** is the ratio of change in length to the original length, when a given body is subjected to some external force (**Strain**= change in length÷the original length).

How Engineers use *Load, stress, strain*

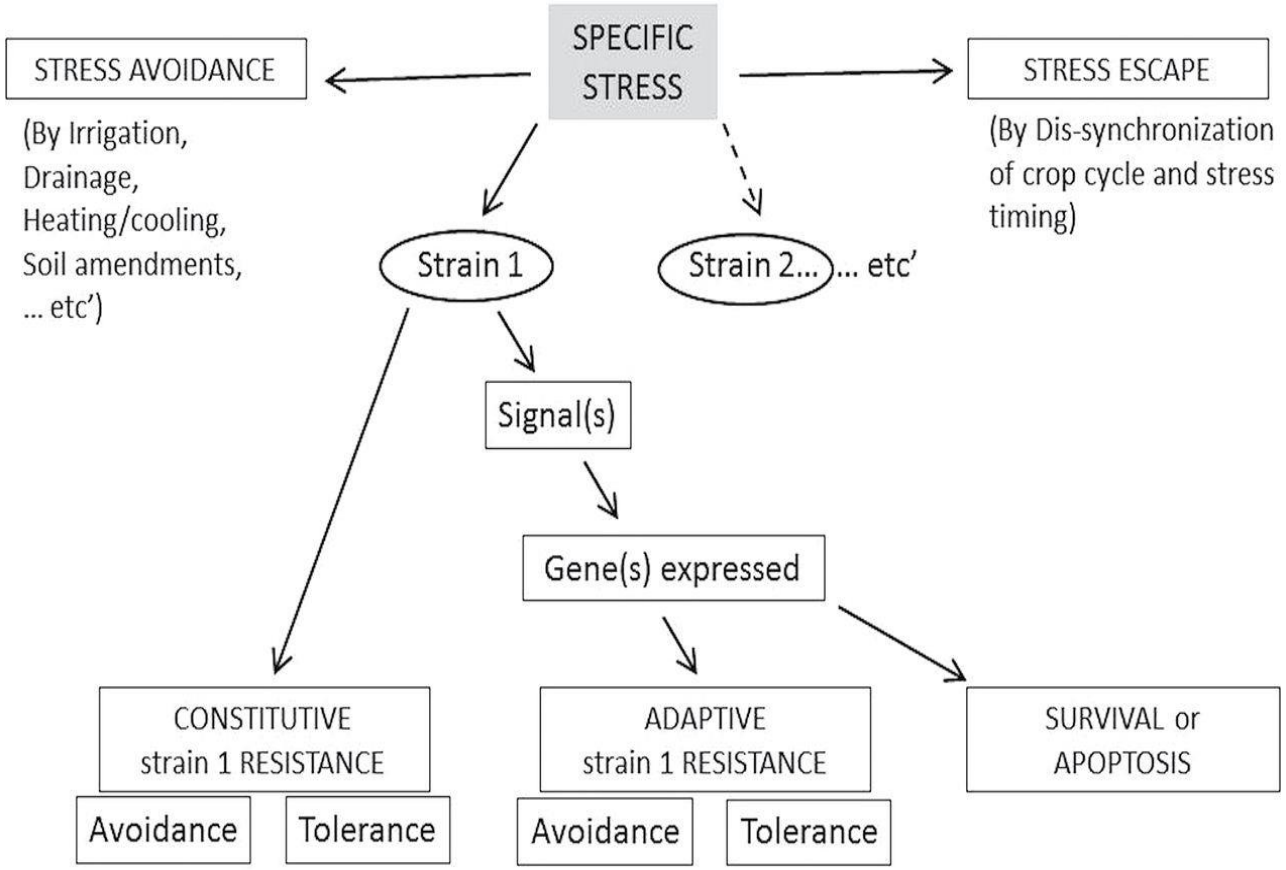


Stress, strain, signaling, and adaptation –not just a matter of definition FREE

Abraham Blum ✉

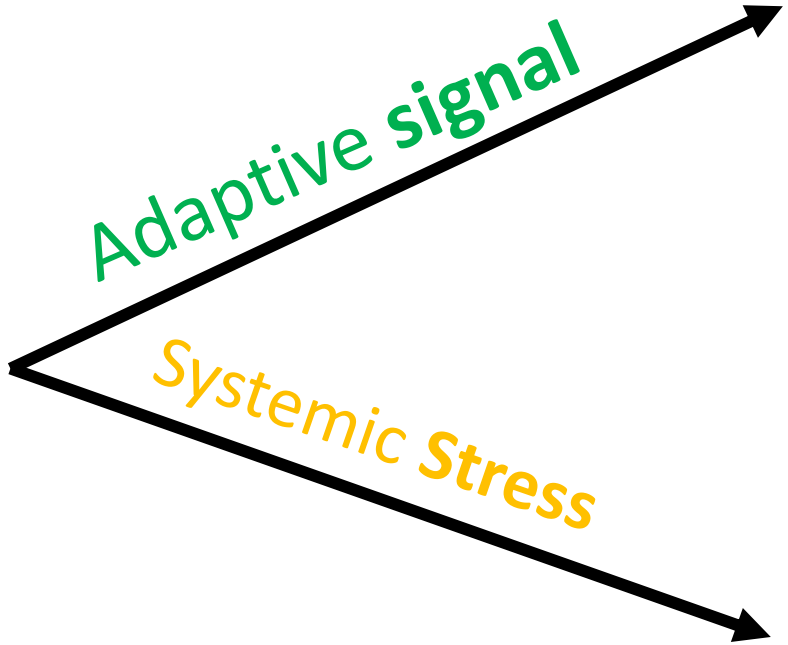
Journal of Experimental Botany, Volume 67, Issue 3, February 2016, Pages 562–565,
https://doi.org/10.1093/jxb/erv497

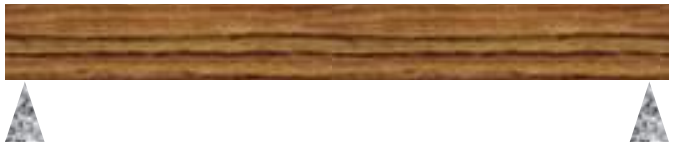
"Genes are not stress-responsive but rather strain-responsive. Furthermore, *a singular unique stress could elicit several different strains and different stresses could elicit the same strain*, with the respective consequences towards gene expression."



Training ***strain*** is not defined by the training load imposed but by the temporary “deformation” of our physiological/psychological systems resulting from mounting the required *stress response.*

Training Loads are actions that we control





Training Adaptations are **results** that we achieve, maintain, and integrate.

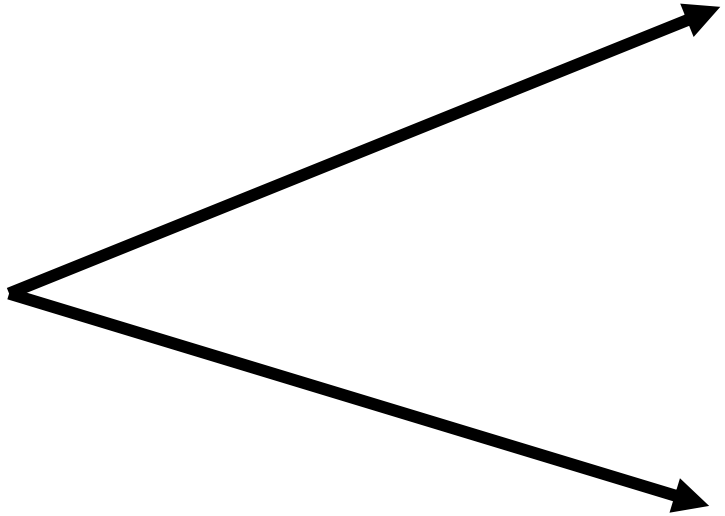
We want these to accumulate!

Strain reactions are “side effects” that we manage and mitigate.

We want the body to “rebound” quickly from the strained state.

We monitor to maximize adaptive stimulus over time at a tolerable and (quickly) reversible level of strain

Training Load



Local/Systemic Adaptation

- Skeletal muscle
- Myocardium
- Vascular network
- Brain

Local/Systemic Strain

- Muscle
- Autonomic Nervous System
- Immune System
- Endocrine System

The Endurance Training Monitoring Trinity

Power/Pace

P3

Physiological Responses

Internal "Cost"

External Work

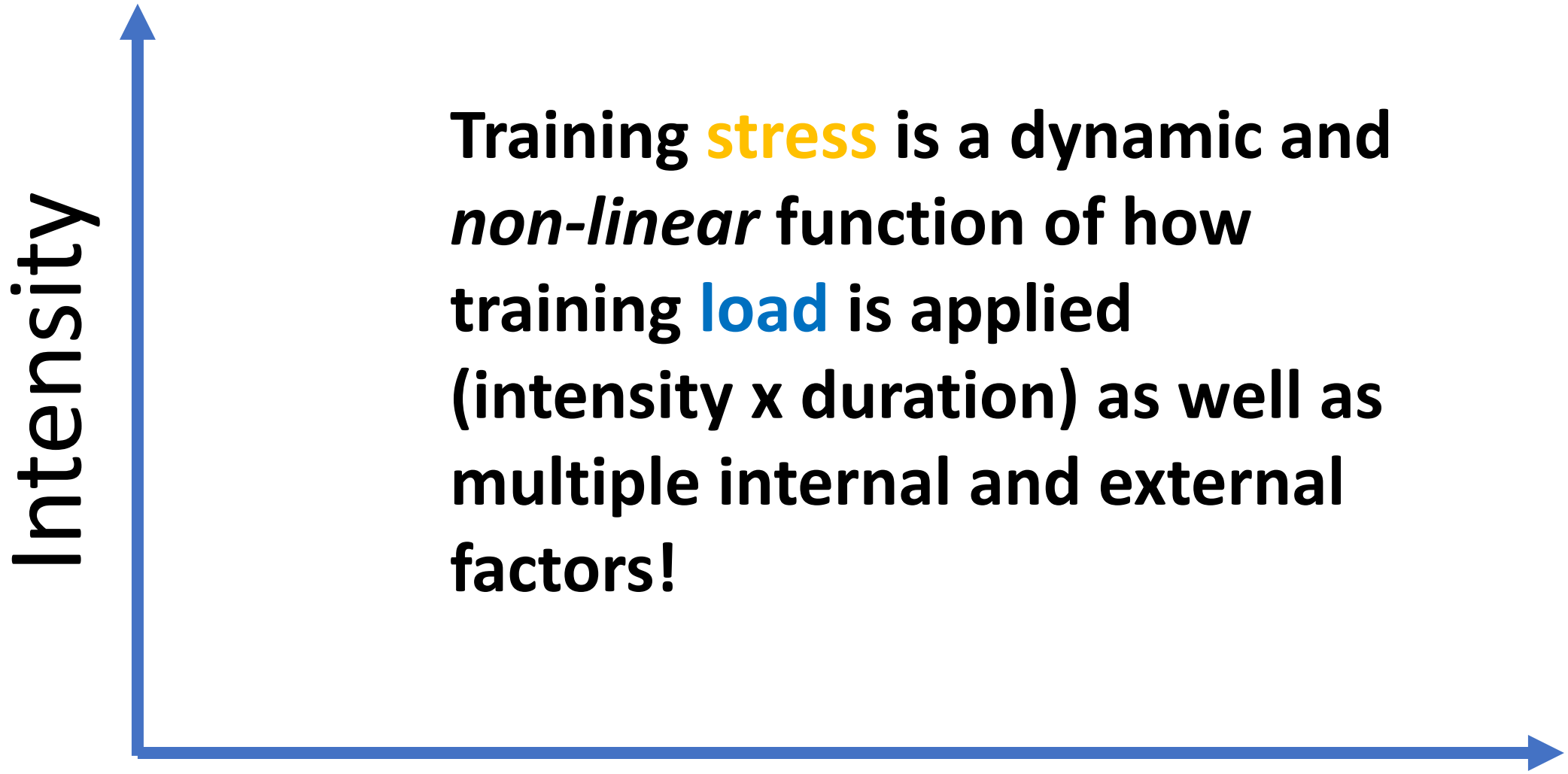
Perceptual Responses

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

Training **load** is “neutral” and only takes on meaning when calibrated against capacity **in two dimensions** (intensity and duration).

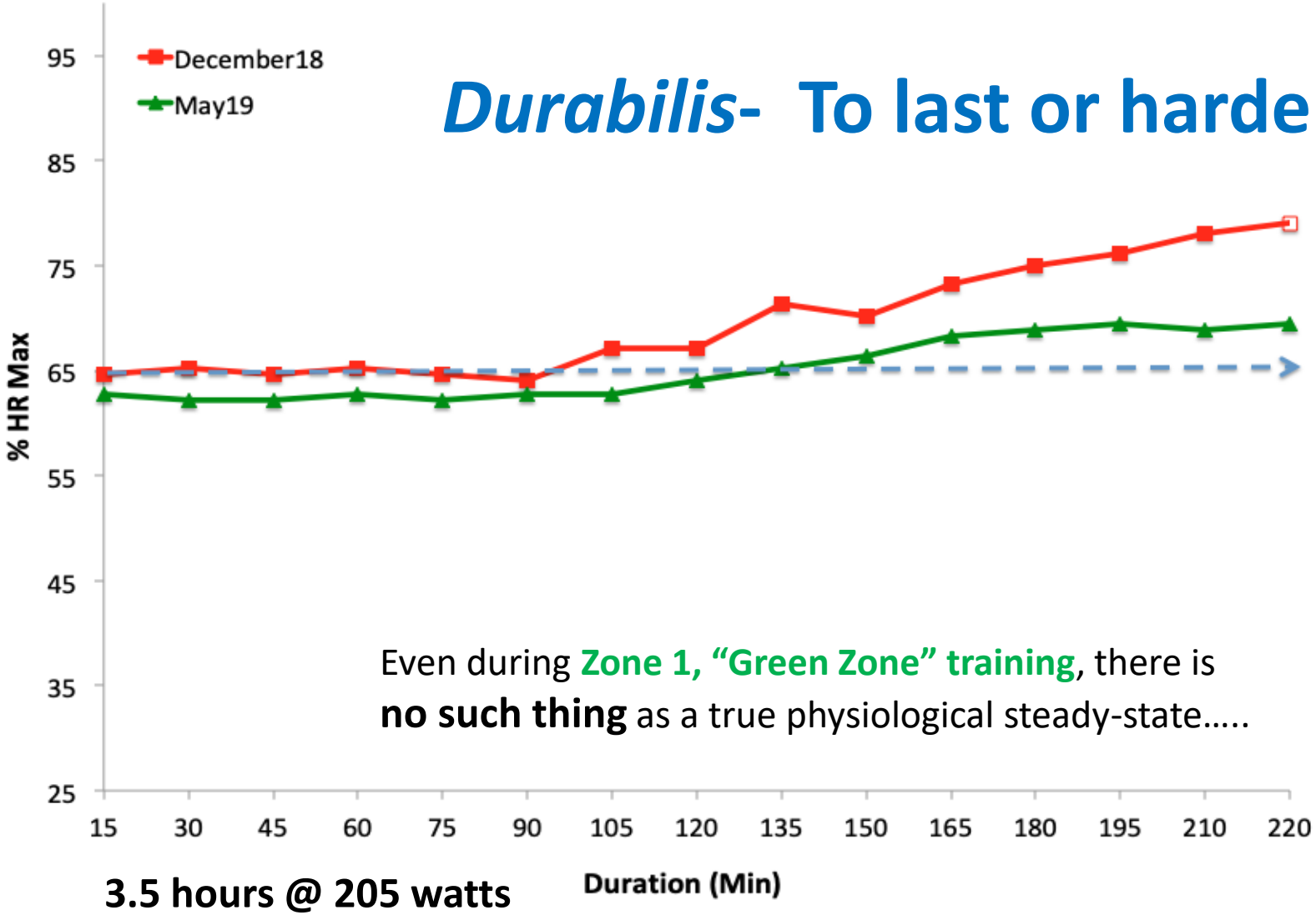
Training **stress** is **acute** (occurs during load), and the stress/load relationship is **dynamic** because **capacity deteriorates** during a workout/race!

Training **strain** is primarily identified through its impact on responses to **subsequent** loads (≥ *24h post training?*). Here, we must distinguish transient *fatigue* from a slower recovering strain response.



Training stress is a dynamic and *non-linear* function of how training load is applied (intensity x duration) as well as multiple internal and external factors!

Increase Duration Tolerance (and reduced STRESS) at the same load……

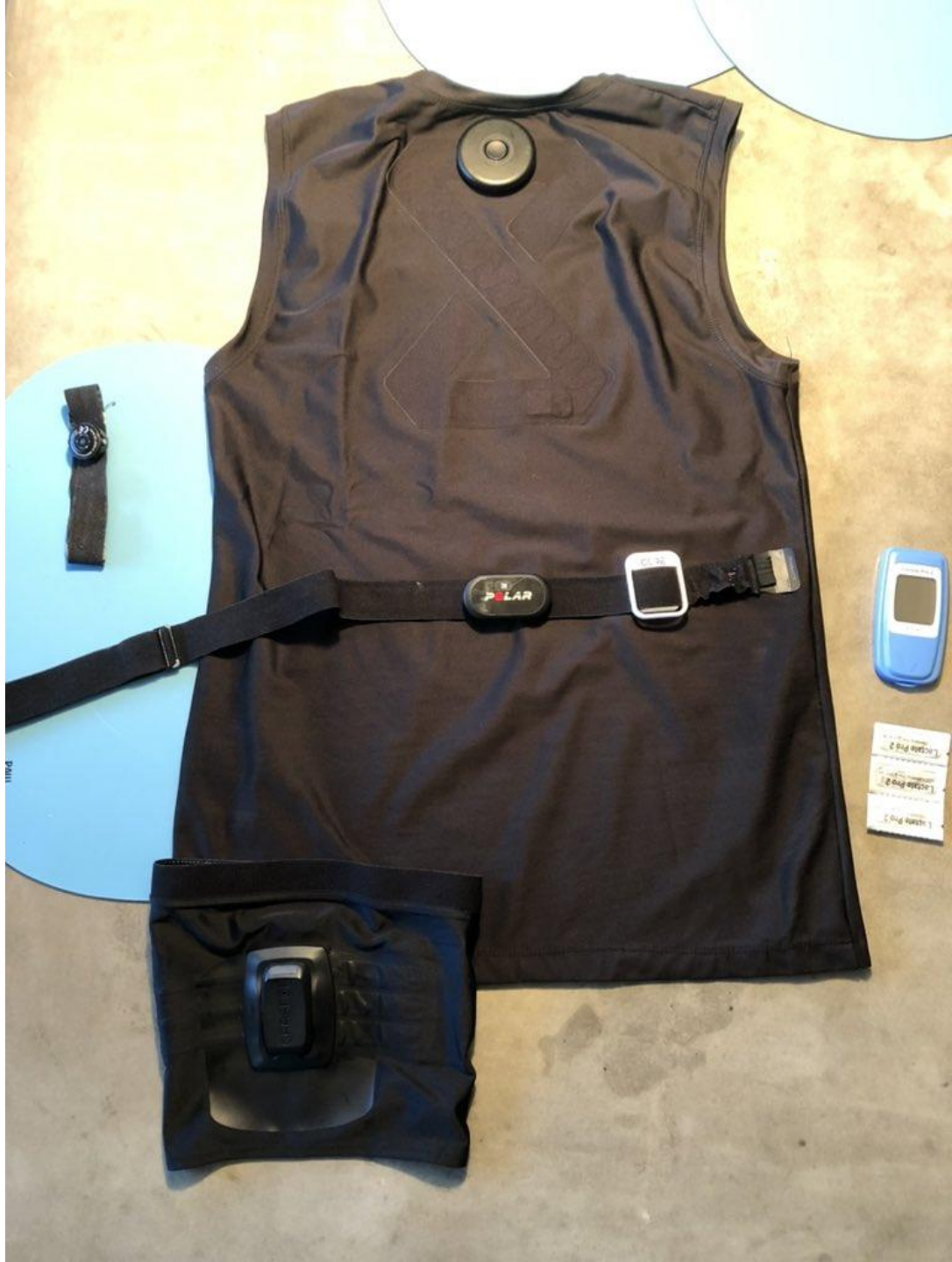


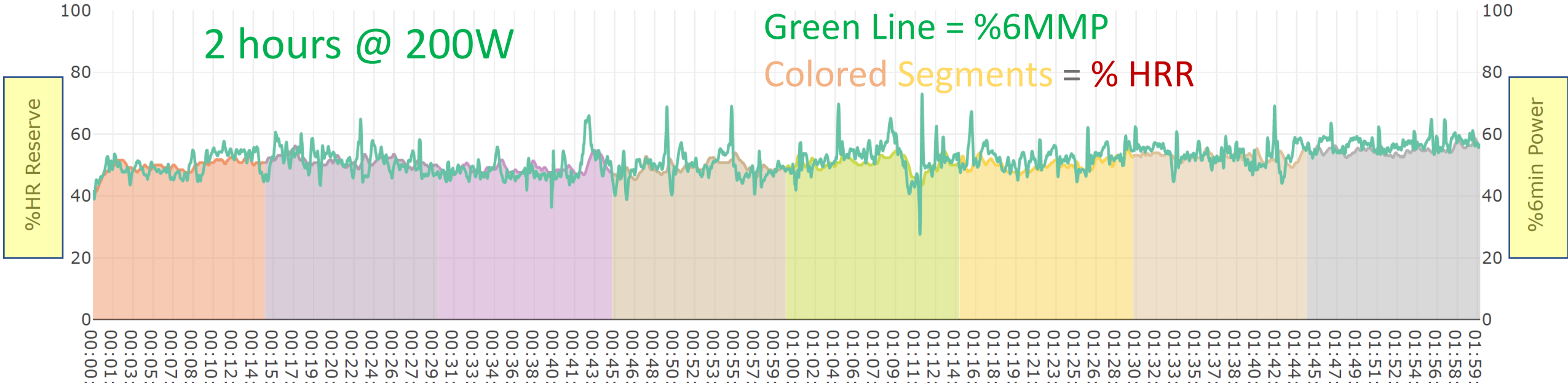
Durabilis- To last or harden

Even during **Zone 1, "Green Zone" training**, there is **no such thing** as a true physiological steady-state…..

3.5 hours @ 205 watts


ZWIFT
ZWIFT

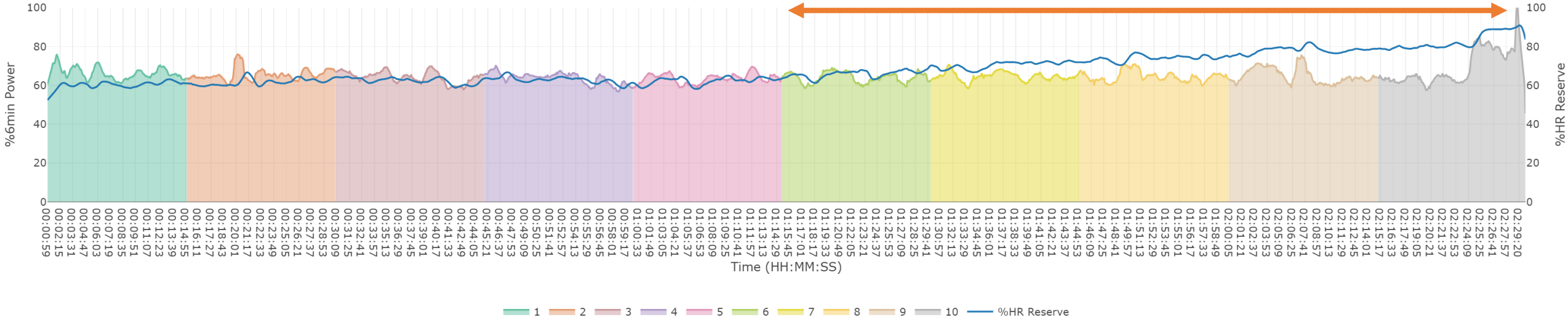

POLAR



Lap	Duration (HH:MM:SS)	Avg Power (W)	Max Power (W)	Raw NP	Avg %6min Power	Avg %60min Power	Avg Watts/KG	Avg %HRR	Avg %Max HR	Avg %HRR/%6min Power	Avg Watts/%HRR
Total	02:00:00	196.7	277.4	198.98	51.76	65.57	2.4	50.88	61.66	0.99	3.87
1	00:15:00	189.36	219.2	190.79	49.83	63.12	2.31	49.58	60.65	1	3.82
2	00:15:00	195.61	246.5	197.16	51.48	65.2	2.39	51.31	62	1	3.82
3	00:15:00	185.03	250.7	187.15	48.69	61.68	2.26	48.96	60.16	1.01	3.78
4	00:15:00	187.65	262.4	189.89	49.38	62.55	2.29	49.09	60.27	1	3.83
5	00:15:00	197.91	277.4	200.83	52.08	65.97	2.41	50.48	61.35	0.98	3.92
6	00:15:00	198.69	255.7	199.99	52.29	66.23	2.42	50.18	61.11	0.96	3.96
7	00:15:00	203.15	262.8	204.41	53.46	67.72	2.48	52.64	63.04	0.99	3.86
8	00:15:00	216.16	246.3	216.65	56.88	72.05	2.64	54.79	64.71	0.96	3.95

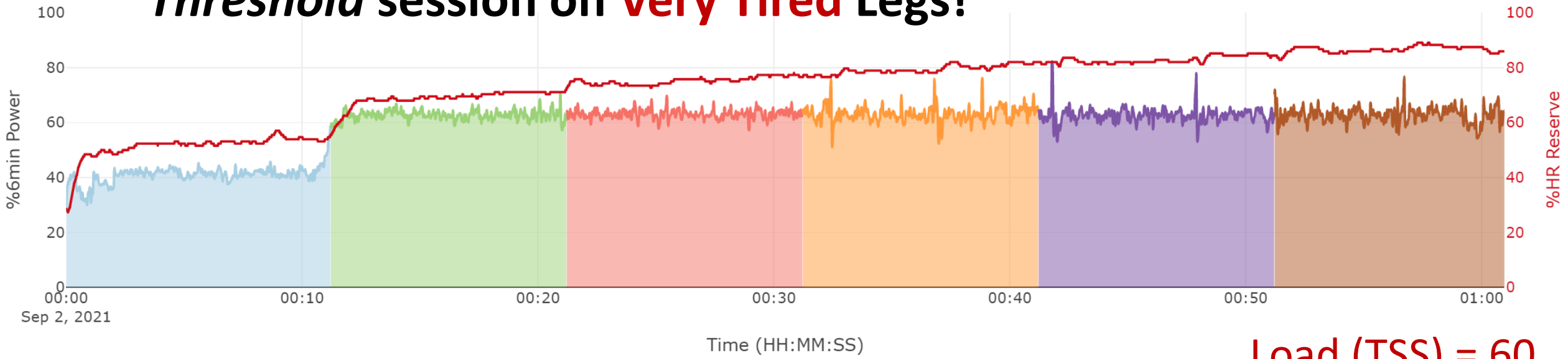
2.5 hours @ 255W

“Decoupling”



Lap	Duration (HH:MM:SS)	Avg Power (W)	Avg %6min Power	Avg %60min Power	Avg Watts/KG	Avg %HRR	Avg %Max HR	Avg %HRR/%6min Power	Avg Watts/%HRR	IN/EX_S
Total	02:30:00	255.8	65.09	82.51	3.12	68.09	75.06	1.05	3.77	
1	00:15:00	260.51	66.29	84.04	3.18	60.24	68.91	0.91	4.05	0.97
2	00:15:00	257.66	65.56	83.12	3.14	61.72	70.07	0.94	4.18	1
3	00:15:00	252.67	64.29	81.51	3.08	62.41	70.61	0.97	4.05	1.03
4	00:15:00	250.54	63.75	80.82	3.06	62.77	70.89	0.98	3.99	1.04
5	00:15:00	249.99	63.61	80.64	3.05	62.28	70.51	0.98	4.02	1.04
6	00:15:00	251.74	64.05	81.2	3.07	65.89	73.34	1.03	3.82	1.09
7	00:15:00	254.05	64.64	81.95	3.1	70.49	76.93	1.09	3.61	1.16
8	00:15:00	253.69	64.55	81.83	3.09	73.93	79.62	1.15	3.43	1.22
9	00:15:00	255.6	65.04	82.45	3.12	78.07	82.85	1.2	3.27	1.27
10	00:15:00	271.94	69.2	87.72	3.32	82.74	86.51	1.2	3.28	1.27

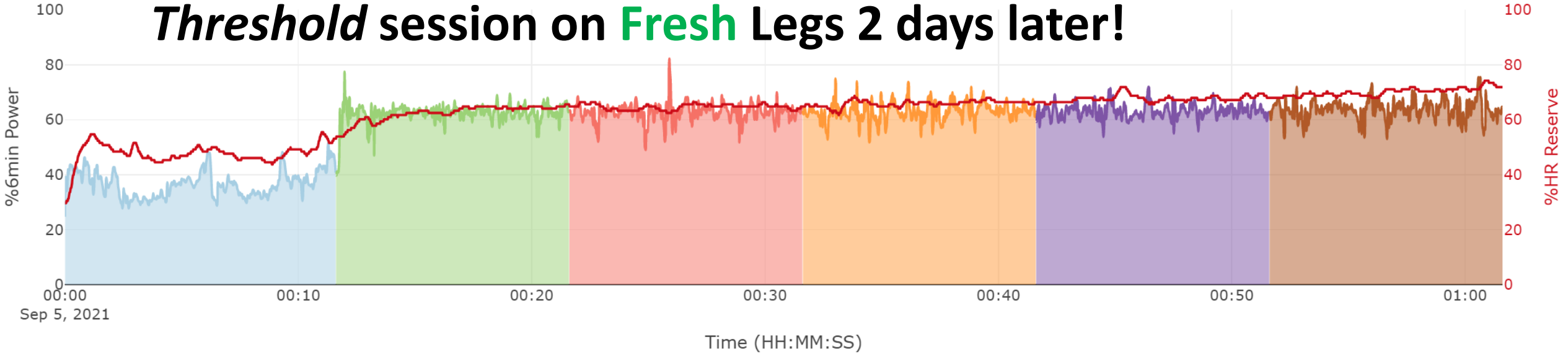
Threshold session on Very Tired Legs!



Load (TSS) = 60

Lap	Duration (HH:MM:SS)	Avg Cadence	Avg Power (W)	Max Power (W)	Quad Power (W)	Avg Watts/KG	Avg Torque (Nm)	Avg %HRR	Avg %Max HR	Avg %HRR/%6min Power	Avg Watts/%HRR	IN/EX_S	Load	Stress	%HRR Delta
Total	01:00:58	84	235.32	329	241.99	2.91	27.32	73.52	79.46	1.25	3.22		59.89	34.09	57.03
1	00:11:12	81	163.82	236	165.24	2.02	23.65	51.3	62.22	1.25	3.22	1.25	5.25	3	26.56
2	00:10:00	85	250.75	283	251.06	3.1	28.04	68.77	75.78	1.1	3.65	1.1	10.91	2.23	16.41
3	00:10:00	85	252.34	279	252.61	3.12	28.21	75.22	80.78	1.19	3.36	1.19	11.05	4.65	3.91
4	00:10:00	85	252.27	305	253.07	3.11	28.2	79.3	83.95	1.26	3.18	1.26	11.06	6.4	5.47
5	00:10:00	85	250.68	329	251.44	3.09	28.11	82.89	86.73	1.32	3.02	1.32	10.92	8.15	2.34
6	00:09:46	85	251.12	307	251.89	3.1	28.19	86.65	89.64	1.38	2.9	1.38	10.7	9.65	1.56

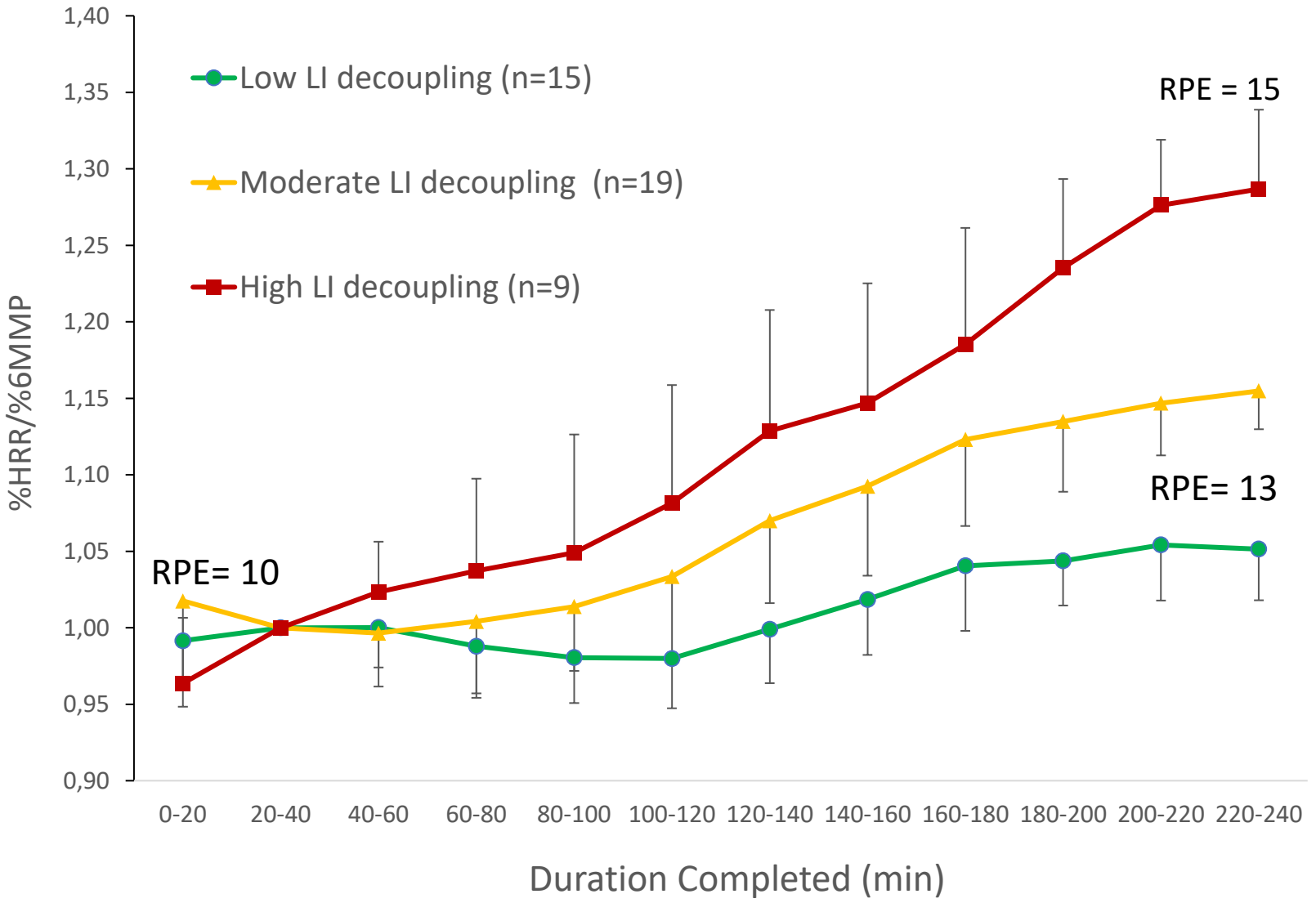
Threshold session on Fresh Legs 2 days later!

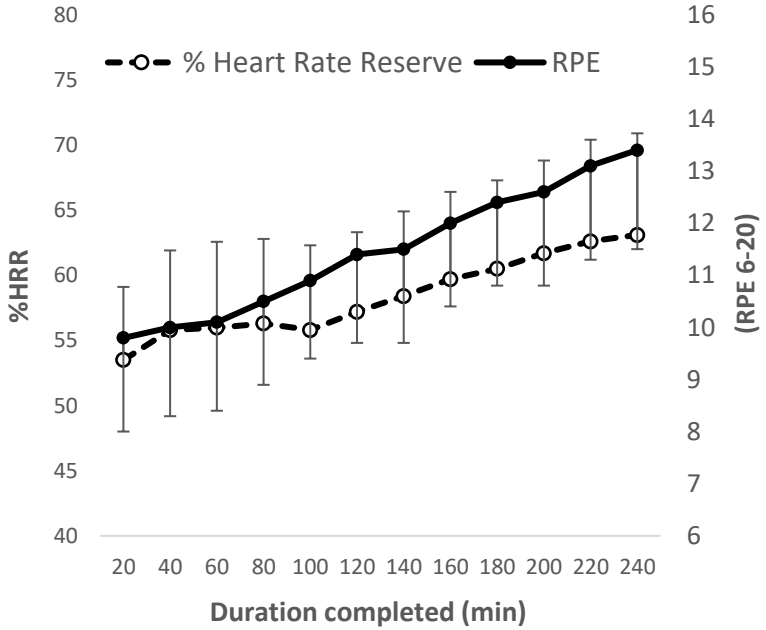


Load (TSS) = 60

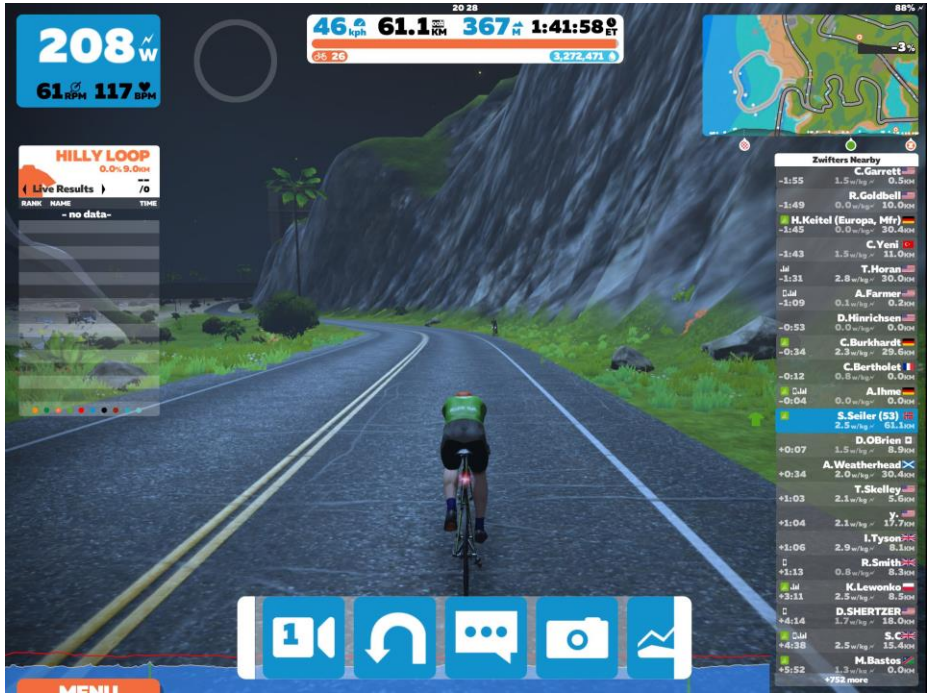
Lap	Duration (HH:MM:SS)	Avg Cadence	Avg Power (W)	Max Power (W)	Quad Power (W)	Avg Watts/KG	Avg Torque (Nm)	Avg %HRR	Avg %Max HR	Avg %HRR/%6min Power	Avg Watts/%HRR	IN/EX_S	Load	Stress
Total	01:01:36	79	232.21	329	241.91	2.87	28.71	62.67	71.04	1.08	3.68		59.65	8.58
1	00:11:36	80	147.16	207	150.93	1.82	19.95	47.74	59.46	1.3	3.1	1.3	4.43	2.95
2	00:10:00	77	248.91	310	250.1	3.07	30.92	62.36	70.8	1	4	1	10.78	0.03
3	00:10:00	79	251	329	252.06	3.1	30.54	64.69	72.61	1.03	3.88	1.03	10.96	0.66
4	00:10:00	78	252.3	300	253.4	3.11	31.14	65.88	73.53	1.04	3.83	1.04	11.07	0.97
5	00:10:00	79	252.65	288	253.3	3.12	30.73	67.67	74.92	1.07	3.74	1.07	11.09	1.62
6	00:10:00	80	255	302	256.22	3.15	30.38	70.13	76.83	1.1	3.64	1.1	11.31	2.34

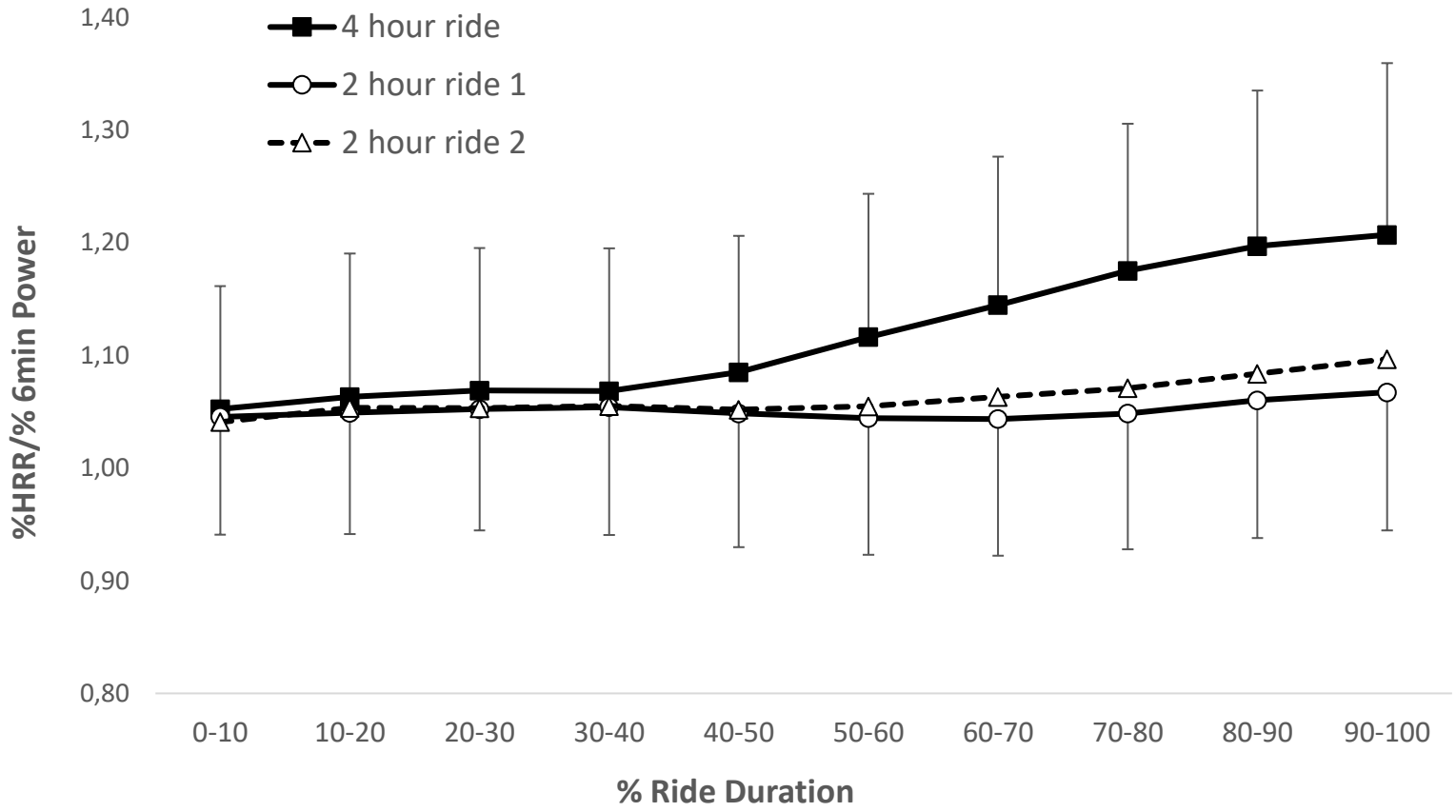
4-hour ride at 60-70% estimated 60min FTP

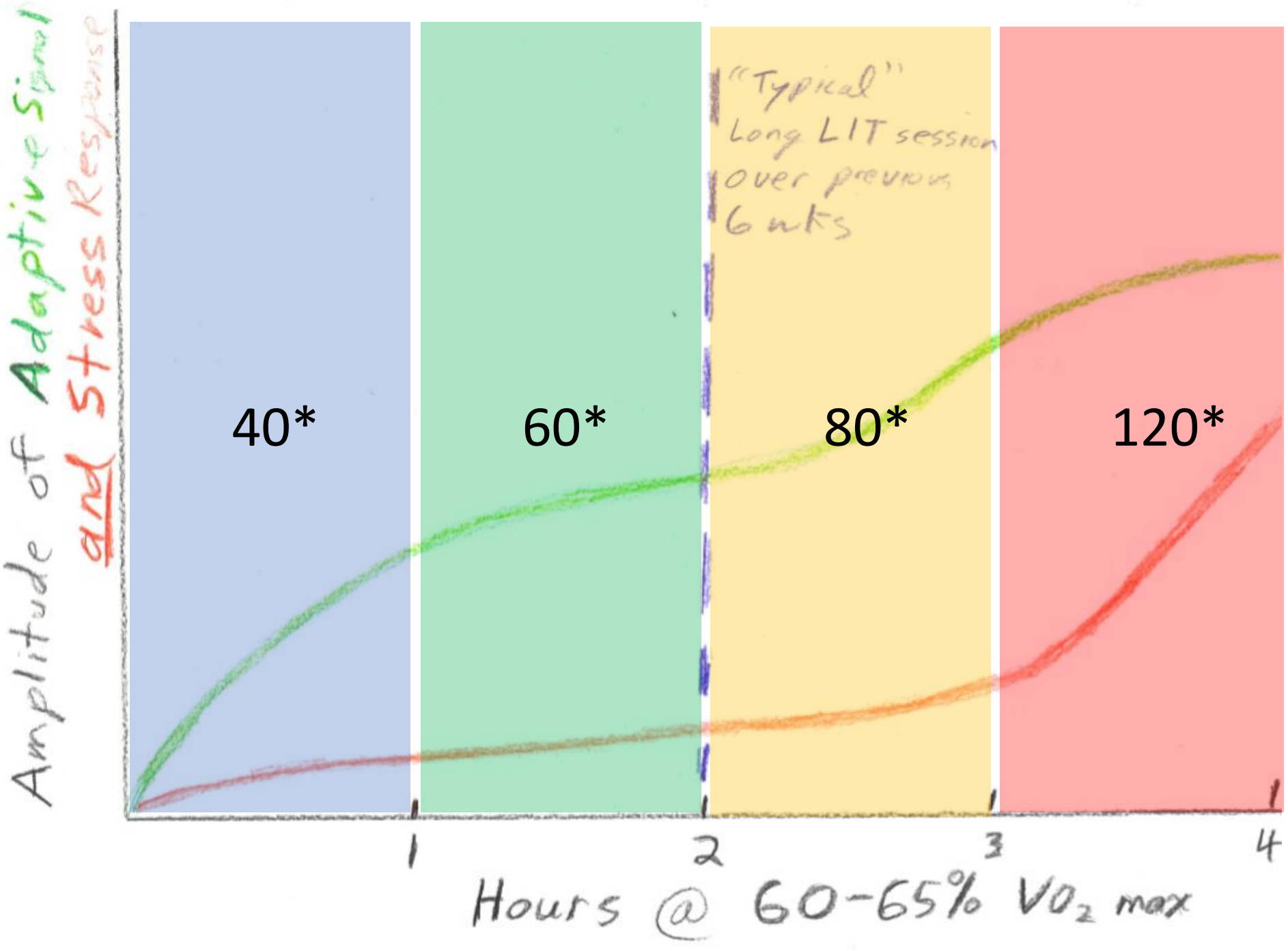




4 hour “Zone 1” ride vs 2 x 2 hours at same intensity (n=43)

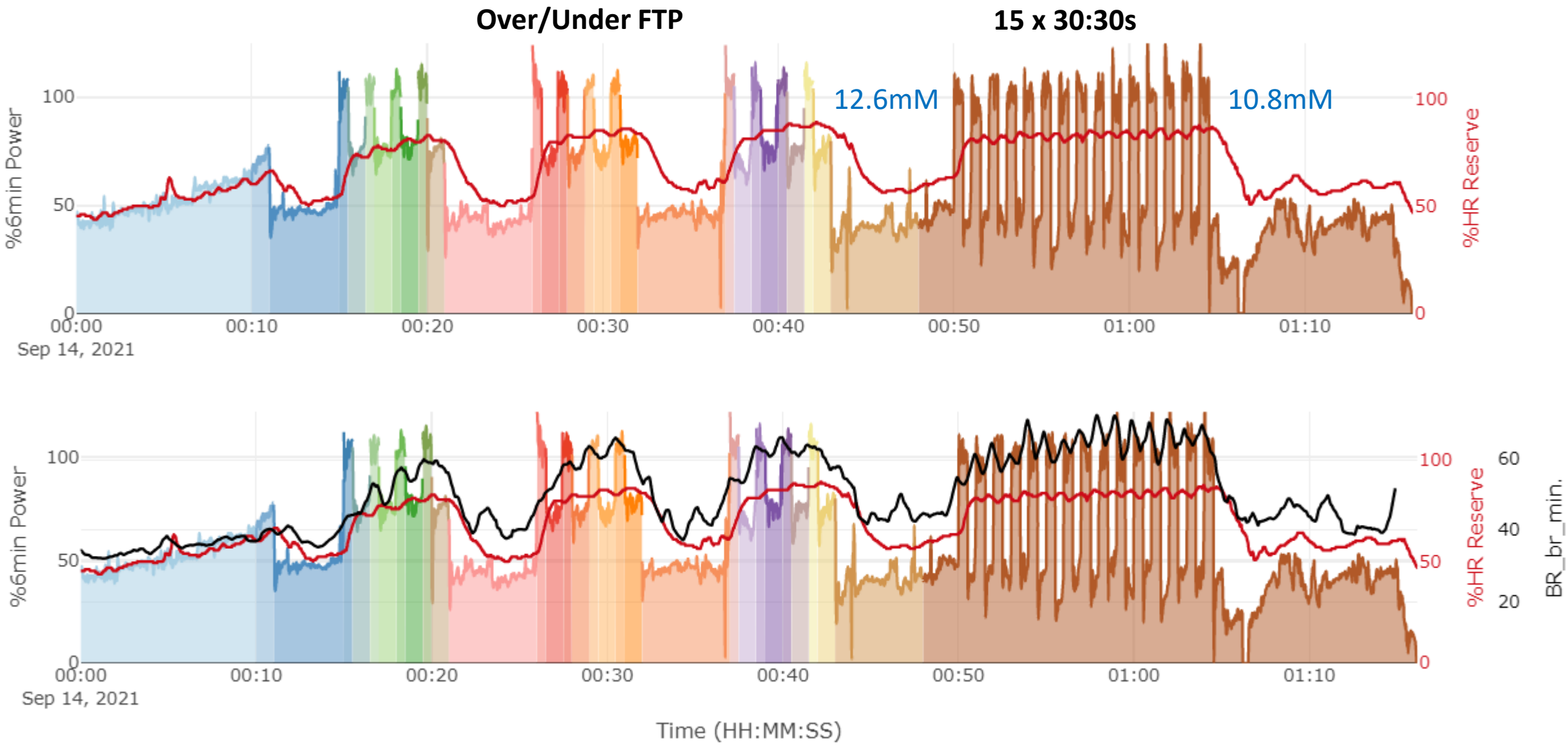


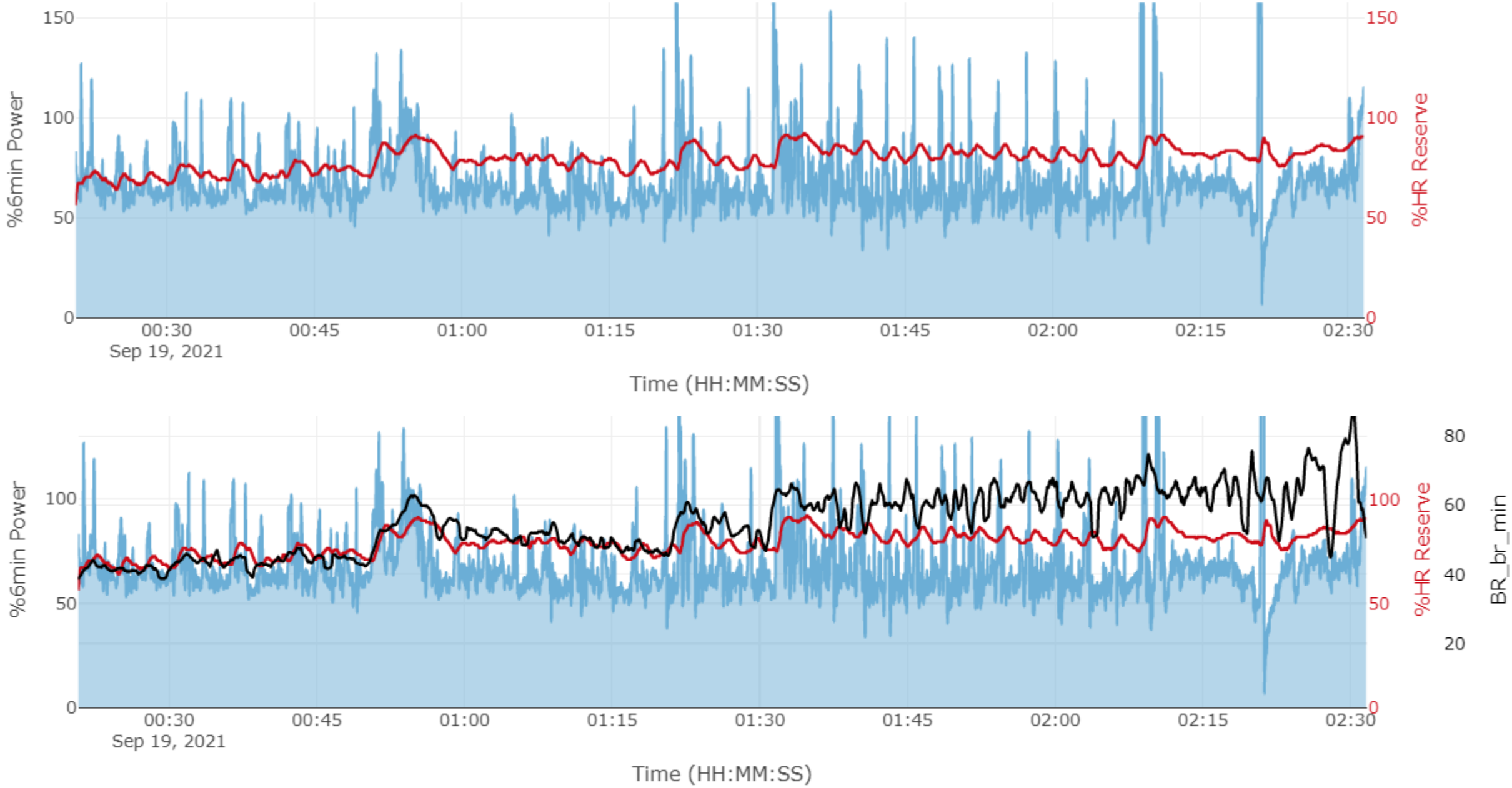




*HSS Hypothetical Seiler Stress Points

Quantifying increasing internal stress during high intensity exercise….??
Heart rate fails due to “ceiling effect”




150
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0
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40
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02:00
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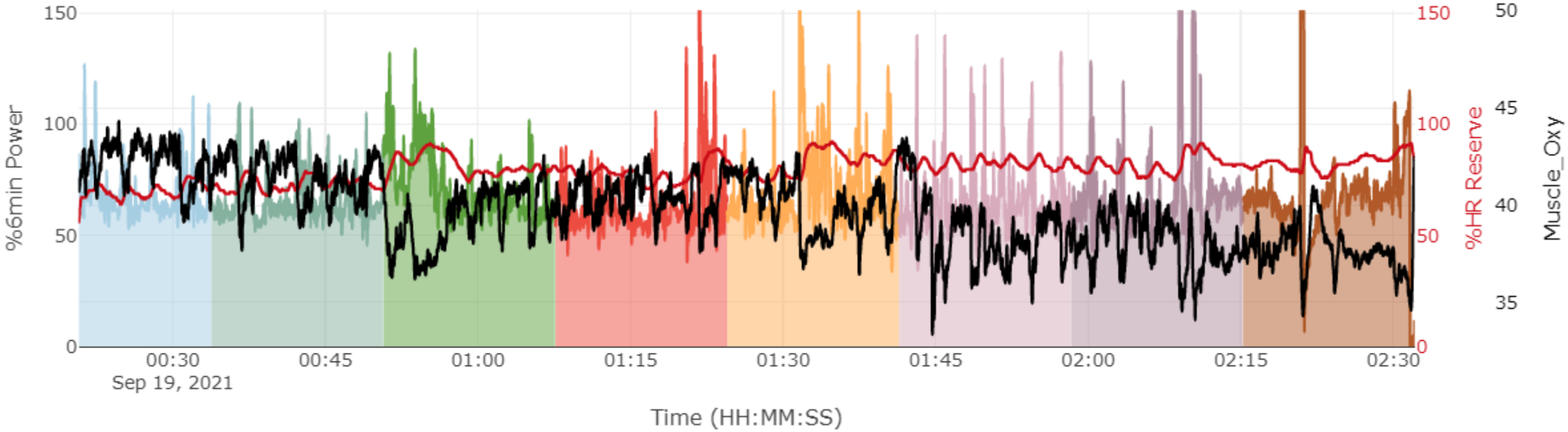
Time (HH:MM:SS)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