Klinikum rechts der Isar
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Training according to CPET results

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Clinical range of exercise prescription

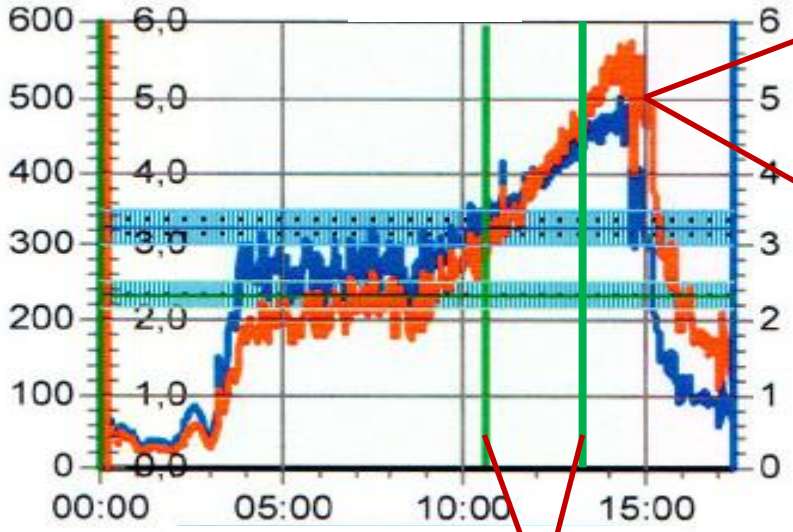
ATHLETE

PATIENT

Clinical range of exercise prescription

CPET-variables for exercise prescription

Heart rate or VO_2 reserve:
((Max – Rest) x % + Rest)



VO_2peak

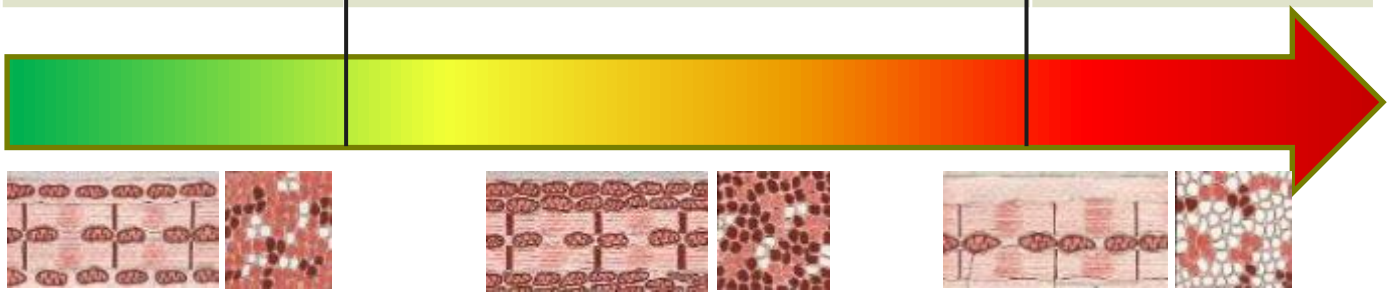
HRmax

Thresholds

Borg scale

Common intensities for exercise

Variable	Low	Moderate	Vigourous	High
HRmax	< 50%	50-70%	70-85%	85-95%
VO_2peak	< 40%	40-60%	60-80%	80-90%
HRR	< 40%	40-60%	60-80%	80-90%
VO_2R	< 40%	40-60%	60-80%	80-90%
Thresholds	< VT1	VT1 – VT2		=> VT2



Riebe D. ACSM‘s Guidelines for Exercise for Exercise Testing and Prescription, 9th ed. (2014)

VO_2peak for exercise prescription

Advantages:

- Most common, internationally recognized exercise parameter used in cardiovascular sports medicine research
- Gold standard for assessment of exercise capacity
- Reflects capacity of whole „system“
- Is thus directly related to physiological exercise capacity
- Can easily be translated to MET [-hours]
- Can be compared to other trials

“$\dot{V}O_{2peak}$ is defined as the highest $\dot{V}O_2$, averaged over a 20 to 30-s period, achieved at presumed maximal effort during an incremental exercise test”

Mezzani, A et al. Eur J of Cardiov Prev and Rehabil. 2009;16:249

Prescribing moderate exercise (50-60%)

ID-Nr: 000020526893
Bemerkung:

181 cm, 86 kg, männl. *23.08.1940 =72J
gemessen am 08.08.2013 /12:01h

SpiroErgometrie - Tabelle

Zeit MM:SS	Last W	HR b/min	BF l/min	VT l	VE l/min	VO2 l/min	VO2/kg ml/min/kg	O2Puls ml/beat	VCO2 l/min	RER	EQCO2	EQO2
Ruhe												
1:00	0	48	9	2.01	18.0	0.32	3.77	7	0.33	1.03	51	53
1:56	0	62	9	1.93	18.3	0.28	3.30	5	0.31	1.10	56	61

"$\dot{V}O_2$peak is defined as the highest $\dot{V}O_2$, averaged over a 20 to 30-s period, achieved at presumed maximal effort during an incremental exercise test"

1:00	20	65	11	1.69	18.0	0.39	4.54	6	0.35	0.89	49	43
1:10	30	66	12	1.74	20.3	0.44	5.09	7	0.39	0.89	49	44
1:20	30	67	13	1.79	22.4	0.48	5.57	7	0.43	0.89	50	44
1:30	30	67	13	1.89	23.9	0.52	6.02	8	0.46	0.89	49	44
1:40	30	68	13	1.76	23.5	0.52	6.03	8	0.46	0.89	48	43
1:50	30	69	14	1.61	22.9	0.54	6.23	8	0.45	0.85	47	40
2:00	30	70	16	1.42	22.2	0.53	6.17	8	0.43	0.81	48	39
2:10	40	71	17	1.24	21.3	0.53	6.13	7	0.40	0.75	49	37
2:20	40	71	17	1.14	18.8	0.48	5.59	7	0.35	0.73	49	36
2:30	40	71	16	1.26	19.7	0.54	6.32	8	0.38	0.70	47	33
2:40	40	72	15	1.55	22.6	0.64	7.40	9	0.46	0.72	46	33
2:50	40	72	14	1.87	25.5	0.71	8.24	10	0.53	0.75	45	34
3:00	40	73	13	1.98	25.8	0.71	8.23	10	0.56	0.78	44	35
3:10	50	74	13	2.13	26.9	0.75	8.74	10	0.60	0.79	43	34
3:20	50	75	13	1.94	26.1	0.72	8.32	10	0.58	0.81	43	35
3:30	50	74	15	1.72	25.0	0.71	8.20	9	0.56	0.79	42	33
3:40	50	74	16	1.57	25.4	0.73	8.47	10	0.57	0.78	42	33
3:50	50	74	19	1.30	24.5	0.69	8.06	9	0.52	0.76	43	33
4:00	50	74	18	1.43	26.4	0.74	8.57	10	0.56	0.76	44	33
4:10	60	74	18	1.55	27.2	0.75	8.76	10	0.59	0.78	43	34
•	•		•		•	•	•	•	•		•	
8:40	100	91	22	2.23	49.8	1.20	13.95	13	1.21	1.01	39	40
8:50	100	92	24	2.28	53.5	1.23	14.36	13	1.25	1.01	41	41
9:00	100	95	24	2.19	53.1	1.22	14.24	13	1.25	1.02	40	41
9:08	100	96	25	2.02	51.4	1.20	13.91	13	1.24	1.04	39	41

71- 75 bpm

7.0 – 8.5 ml/kg/min

14.2 ml/kg/min

VO_2peak for exercise prescription

Pitfalls:

- VO_2peak does in most cases not represent true maximum capacity
- May be influenced by medication
- In subjects with low exercise capacity: recommended exercise intensities may be lower than resting value!
- Is dependant on a successful CPET
- Must be continuosly updated / adjusted
- Not practical for monitoring exercise
- Limited in oscillatory ventilation

HR_{max} for exercise prescription

Advantages:

- Easy to determine and read out
- May also roughly be estimated by formulas (not my recommendation…)
- Appropriate for exercise prescription in healthy individuals

Pitfalls:

- Strongly influenced by medication or disease (chronotropic incompetence)
- Limited in arrhythmias
- Not linearly correlated with VO_2
- Requires full exhaustion
- In subjects with low exercise capacity: recommended exercise intensities may be lower than resting value!

Limitations are partly overcome by using „reserve models“ (HRR)

Prescribing moderate exercise (50-60%)

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1:56	0	62	9	1.93	18.3	0.28	3.30	5	0.31	1.10	56	61
Belastung												
0:10	20	62	9	1.75	16.6	0.27	3.17	4	0.29	1.07	54	58
0:20	20	62	9	1.77	16.4	0.27	3.14	4	0.29	1.06	54	57
0:30	20	62	9	1.67	15.5	0.25	2.93	4	0.26	1.05	55	58
0:40	20	63	9	1.54	14.5	0.25	2.93	4	0.25	0.99	54	54
0:50	20	64	10	1.62	15.9	0.32	3.76	5	0.30	0.92	50	46
1:00	20	65	11	1.69	18.0	0.39	4.54	6	0.35	0.89	49	43
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58 – 67 bpm

71- 75 bpm

7.1 – 8.5 ml/kg/min

96 bpm

14.2 ml/kg/min

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0:20	20	62	9	1.77	16.4	0.27						57
0:30	20	62	9	1.67	15.5	0.25						58
0:40	20	63	9	1.54	14.5	0.25	2.93	4	0.25	0.99	54	54
0:50	20	64	10	1.62	15.9	0.32	3.76	5	0.30	0.92	50	46
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9:08	100	96	25	2.02	51.4	1.20	13.91	13	1.24	1.04	39	41

58 – 67 bpm

71- 75 bpm

7.1 – 8.5 ml/kg/min

(96-48) x 50% + 48 = 72
(96-48) x 60% + 48 = 77

96 bpm

14.2 ml/kg/min

Borg Scale for exercise prescription

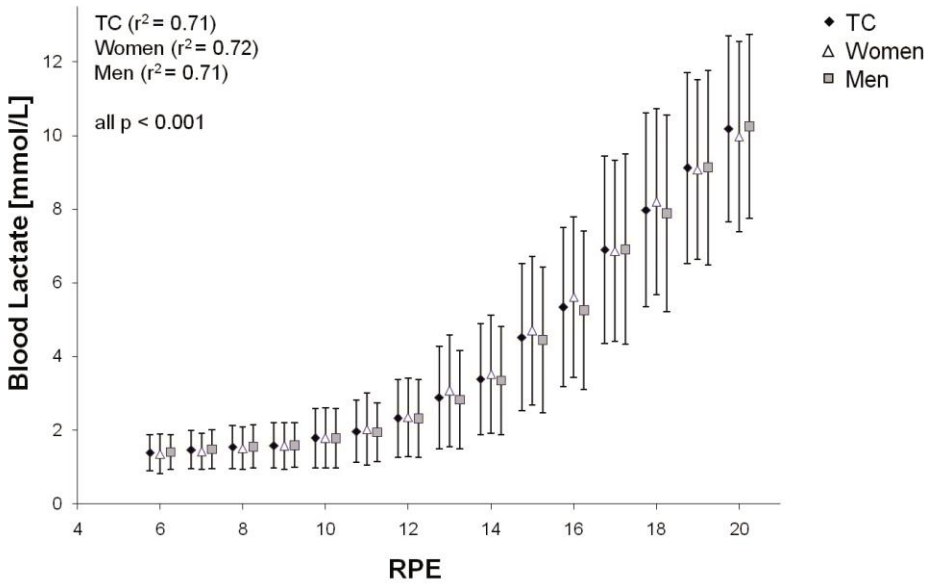
6	No exertion at all
7	
8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

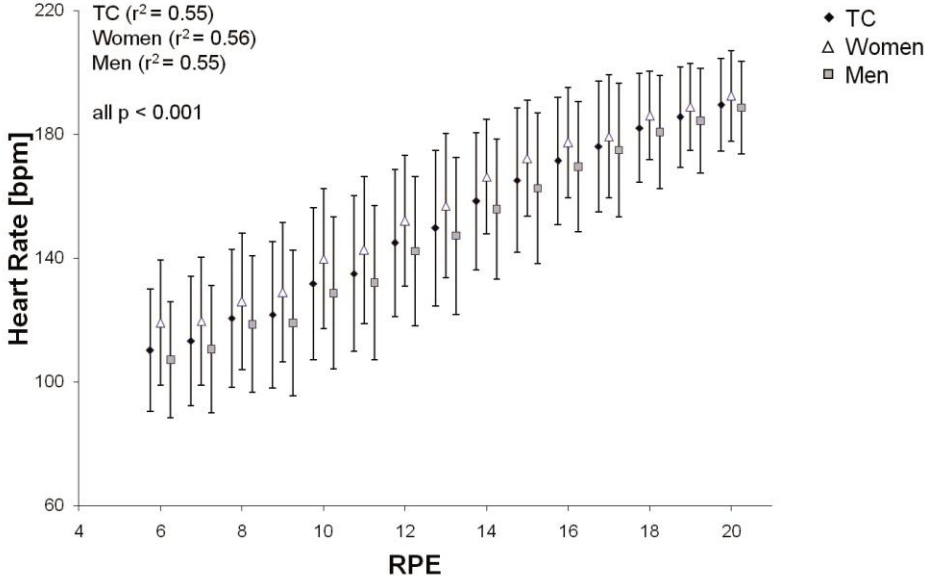
Borg RPE scale
© Gunnar Borg, 1970, 1985, 1984, 1998

0	Nothing at all	"No P"
0.3		
0.5	Extremely weak	Just noticeable
1	Very weak	
1.5		
2	Weak	Light
2.5		
3	Moderate	
4		
5	Strong	Heavy
6		
7	Very strong	
8		
9		
10	**Extremely strong "Max P"**	
11		
⚡		
●	Absolute maximum	Highest possible

Borg CR10 scale
© Gunnar Borg, 1981, 1982, 1998

Borg Scale: association with metabolism

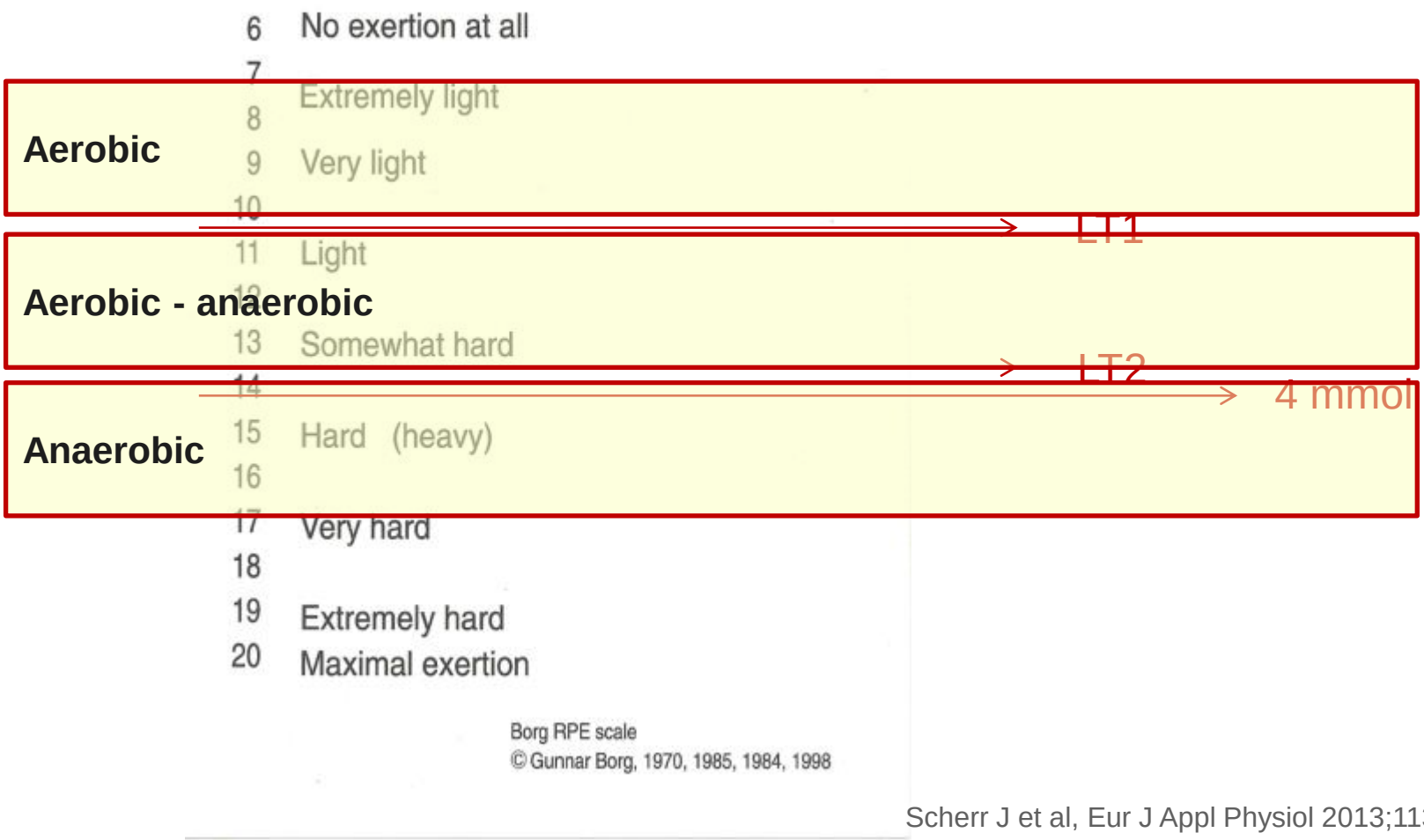




n = 2560 patients (healthy and diseased)

Scherr J et al, Eur J Appl Physiol 2013;113:147-55

Borg Scale for exercise prescription



Scherr J et al, Eur J Appl Physiol 2013;113:147-55

Borg Scale for exercise prescription

Advantages:

- Easy to determine
- Overcomes limitations in subjects with low exercise capacity
- Independant of medication
- Does not require full exhaustion

Pitfalls:

- May strongly over- or underestimate true intensity in some
- Preferable for monitoring rather than prescribing exercise

Mezzani, A et al. Eur J of Cardiov Prev and Rehabil. 2009;16:249

Thresholds for prescribing exercise

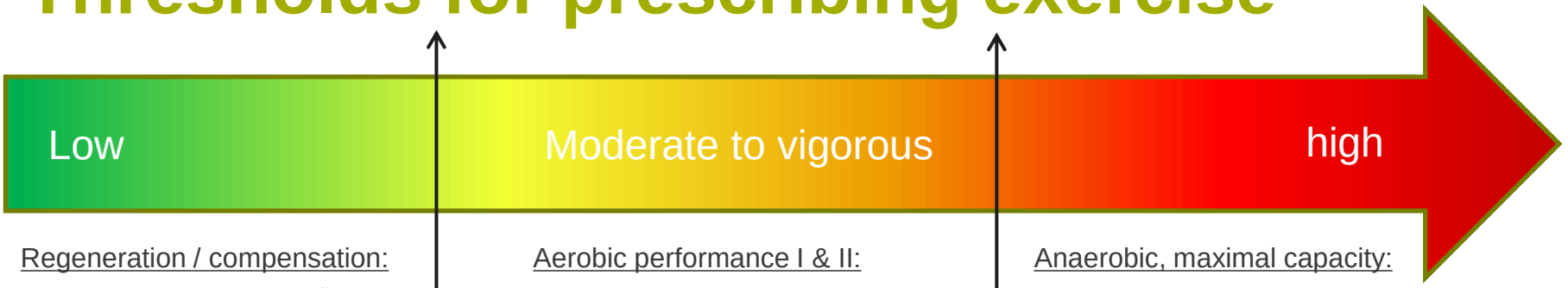
Advantages:

- Do not require full exhaustion
- Directly reflect energy supply during exercise
- Allow for more precise, individualized exercise recommendations
- Independant of medication

Pitfalls:

- Require correct determination of thresholds, which may be challenging in some
- Data on training effects in patient populations is scarce

Thresholds for prescribing exercise



Regeneration / compensation:

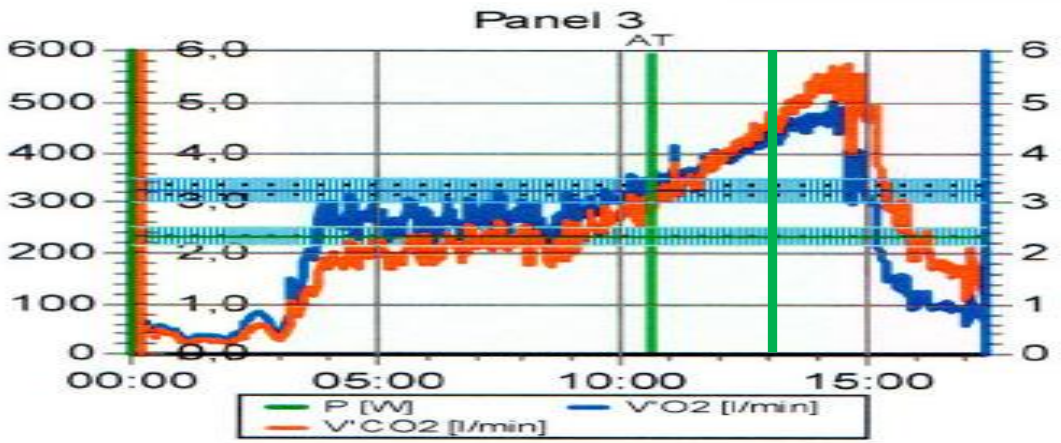
- Exercise for „recovery“ or long-distance training
- Stabilizing rather than increasing performance
- No threshold shift
- Continuous exercise

Aerobic performance I & II:

- Exercise for improving basic aerobic fitness
- Shift of thresholds to higher intensities
- Either as continuous (I) or interval-based exercise (II)

Anaerobic, maximal capacity:

- Exercise for improving peak performance
- Usually no relevant threshold shift
- Increasing „lactate tolerance“
- Performed as interval exercise



Prescribing high-intensity interval training

SpiroErgometrie - Tabelle

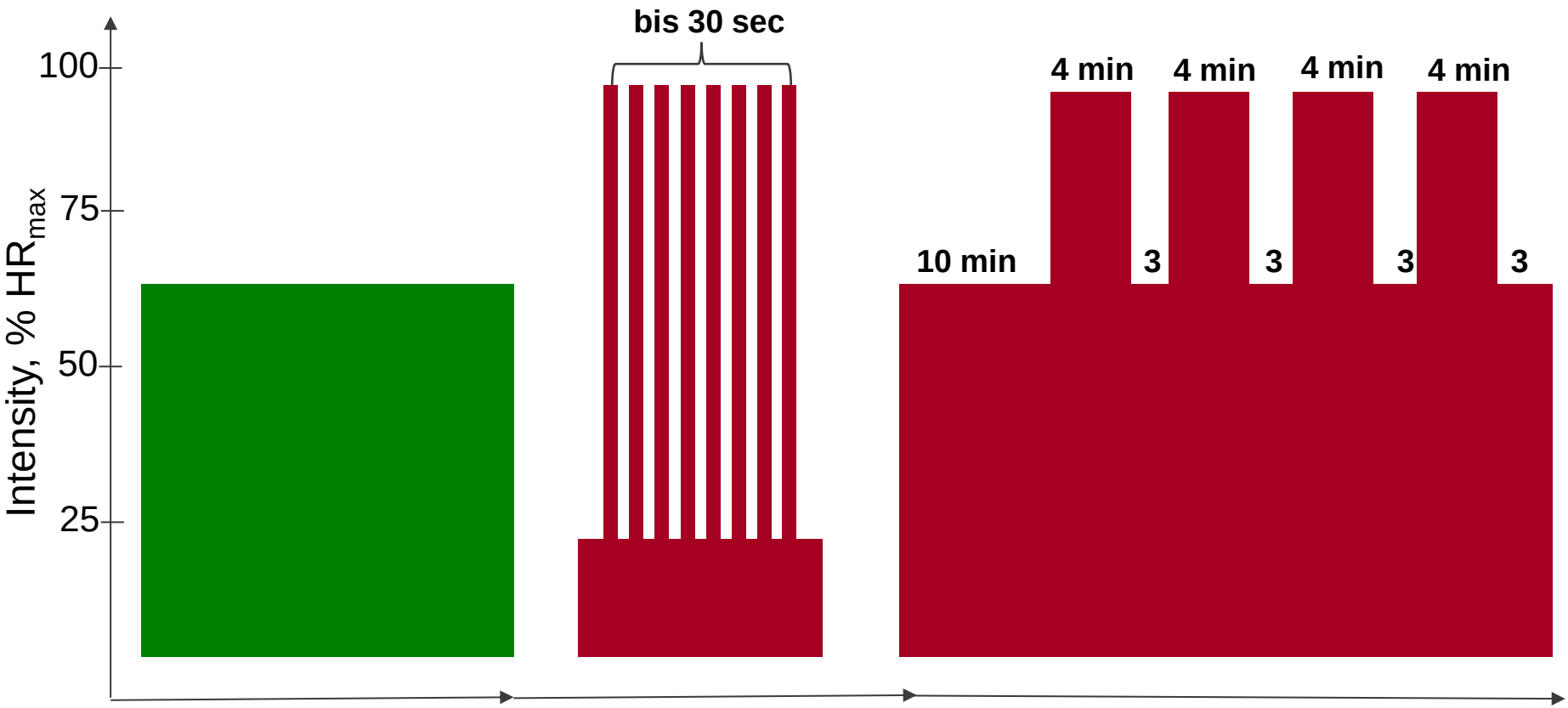
Zeit	Last	HR	BF	VT	VE	VO2	VO2/kg	O2Puls	VCO2	RER	EQCO2	EQO2
MM:SS	W	b/min	1/min	l	l/min	l/min	ml/min/kg	ml/beat	l/min			
Ruhe												
1:00	0	65	16	0.69	11.2	0.34	4.20	5	0.28	0.84	34	29
1:40	0	64	18	0.77	13.8	0.52	6.46	8	0.40	0.78	30	23
•	•	•	•	•	•	•	•	•	•	•	•	•
2:40	40	70	18	1.28	22.4	0.76	9.46	11	0.68	0.90	30	27
2:50	40	73	18	1.24	22.3	0.80	9.98	11	0.70	0.88	29	26
3:00	40	72	17	1.26	22.0	0.81	10.13				29	25
3:10	50	72	18	1.31	23.6	0.89	11.08				29	25
3:20	50	69	19	1.27	24.0	0.91	11.40	13	0.77	0.84	29	24
3:30	50	70	18	1.33	24.1	0.91	11.41	13	0.78	0.86	28	24
•	•	•	•	•	•	•	•	•	•	•	•	•
8:40	100	106	25	1.69	42.8	1.28	15.97	12	1.45	1.14	28	32
8:50	100	103	25	1.73	43.0	1.33	16.58				27	31
9:00	100	104	26	1.70	44.9	1.34	16.80				26	31
9:10	110	104	27	1.70	45.2	1.35	16.87				26	32
9:20	110	105	26	1.68	44.6	1.37	17.15	13	1.58	1.15	26	31
9:30	110	105	27	1.70	46.5	1.44	18.05	14	1.64	1.14	27	30
9:40	110	106	28	1.68	46.7	1.38	17.30	13	1.62	1.17	27	32
•	•	•	•	•	•	•	•	•	•	•	•	•
11:40	130	120	34	1.74	59.7	1.52	18.97	13	2.03	1.34	28	37
11:50	130	121	35	1.81	62.8	1.56	19.54			1.35	28	38
12:00	130	122	34	1.72	59.1	1.49	18.63			1.31	29	37
12:10	140	123	35	1.78	62.0	1.60	20.01			1.28	29	37

50-60% VO_2peak

80-90% VO_2peak

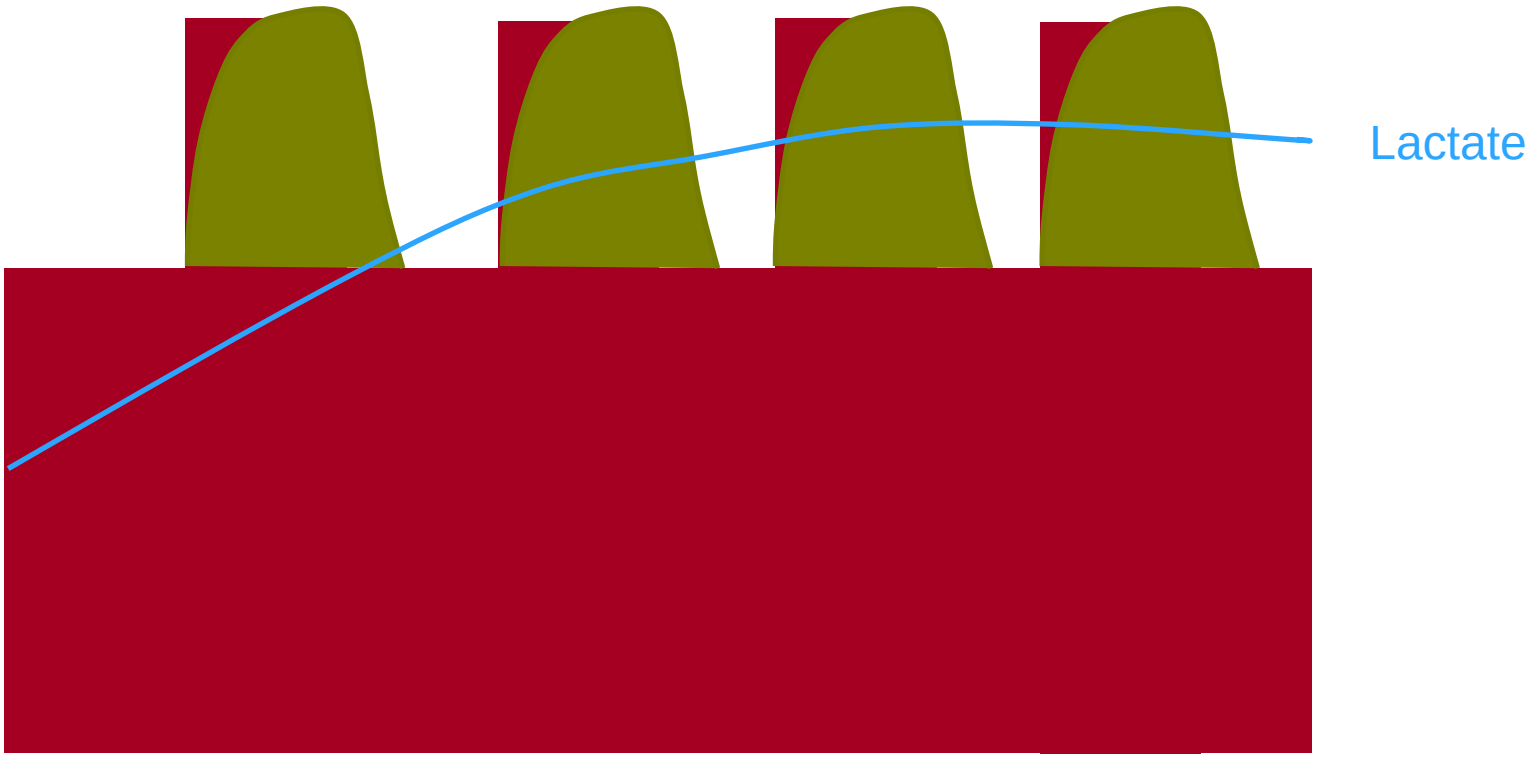
VO_2peak

Training protocols



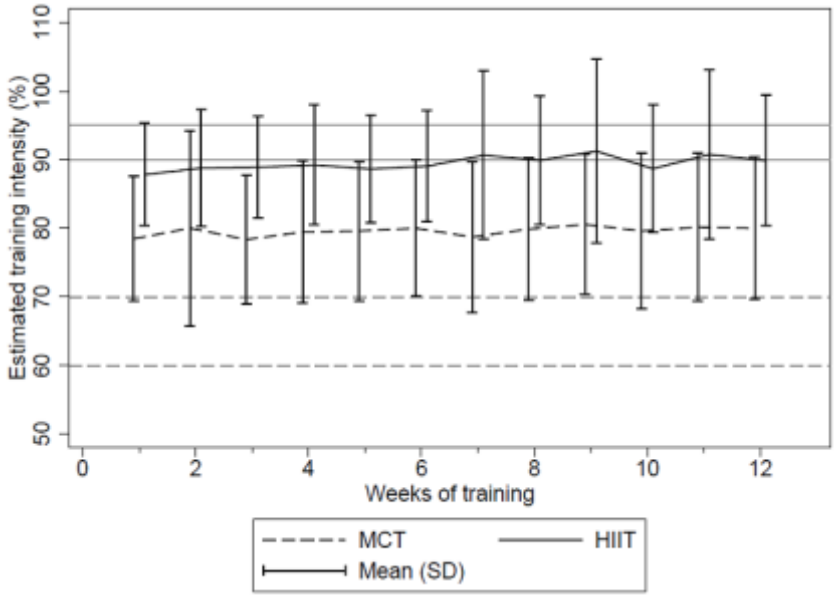
Pressler A, Herzmedizin 2013;2:24

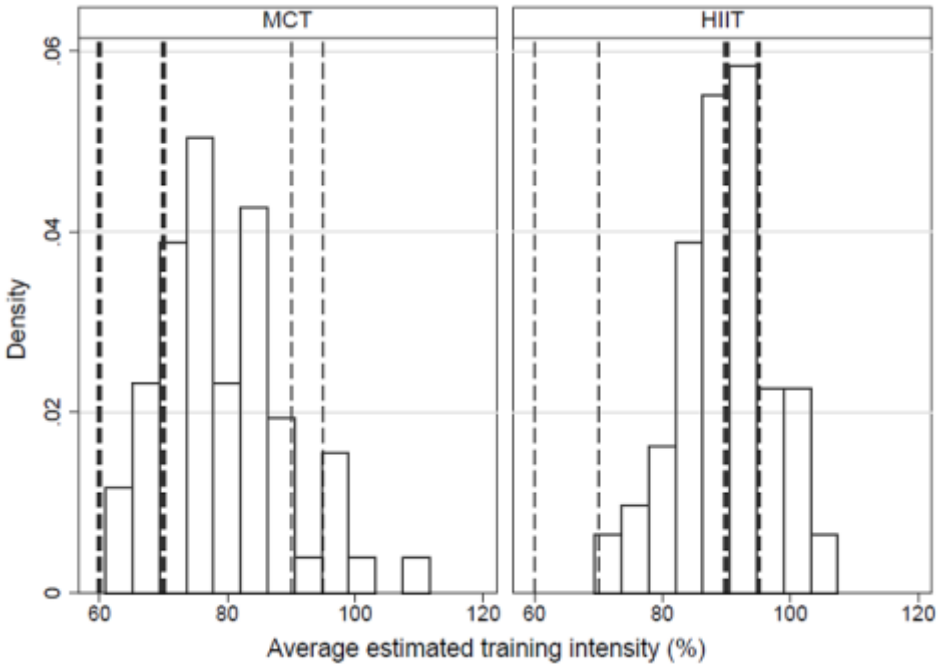
Physiologie during intervals



Monitoring interval exercise

Always monitor and adjust intensities!





Ellingsen O et al, submitted

Summary and conclusion

- In patient populations and cardiac rehabilitation, CPET with determination of VO_2peak is the key component of prescribing exercise at different intensities
- Threshold concepts are less well established in rehabilitation but probably allow for a more precise, individualized recommendation (more data needed)
- Concepts based on maximal heart rate are limited by medication or the disease itself and should not be used in patient populations
- The Borg Scale is a helpful tool to calculate and monitor intensities that cannot be determined by objective means
- Exercise intensities need monitoring and regular adjustment particular in research settings

Kontakt

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