



ALFA : NIMS HYDRABAD 2025

Cardio-Pulmonary Exercise Test : CPET

Deepak Talwar

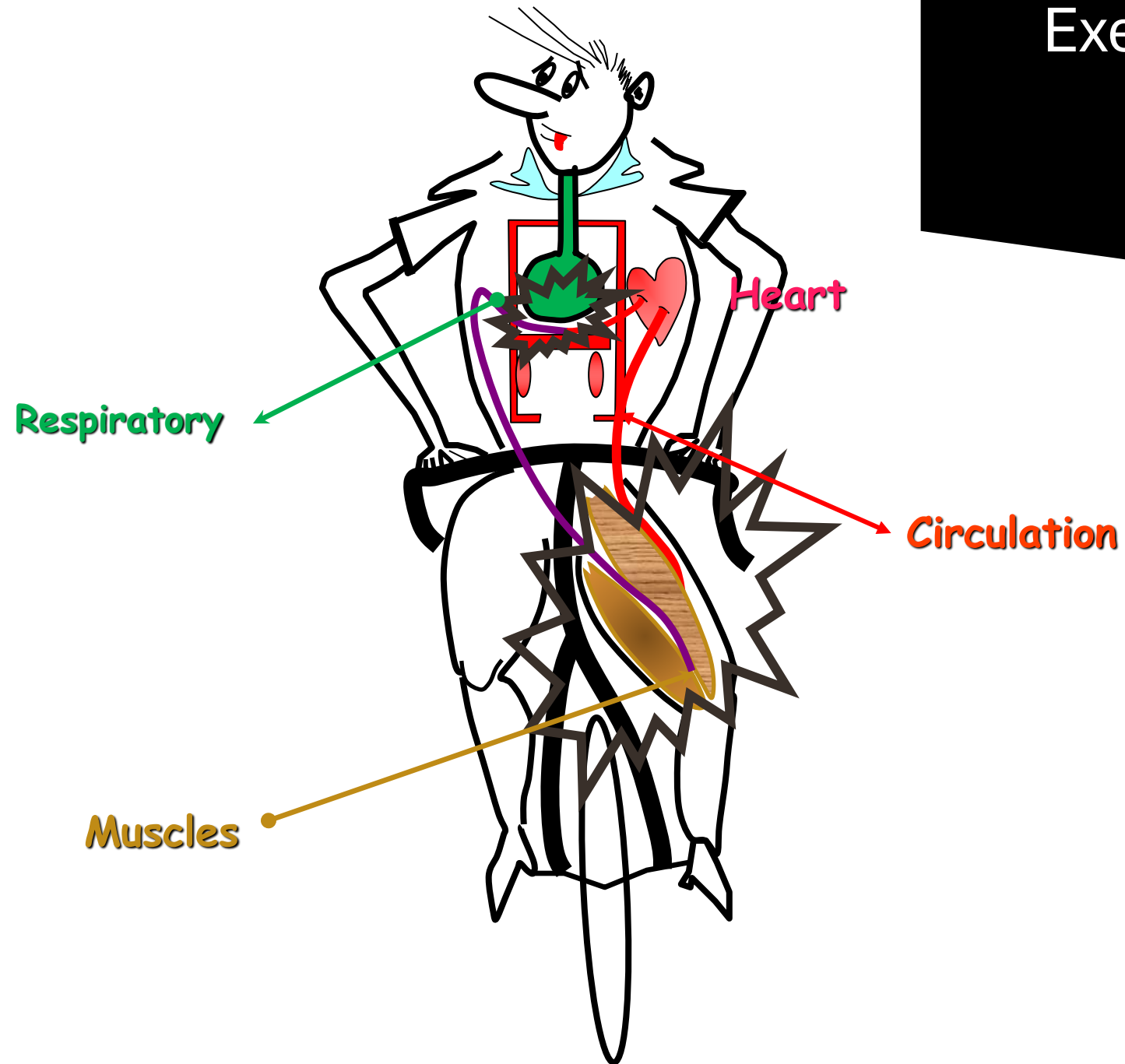
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Director & Chair

Pulmonary, Sleep, Allergy & Critical Care Medicine

Metro Group of Hospitals, INDIA

Exercise Test to Find Out Cause of Exercise Limitation

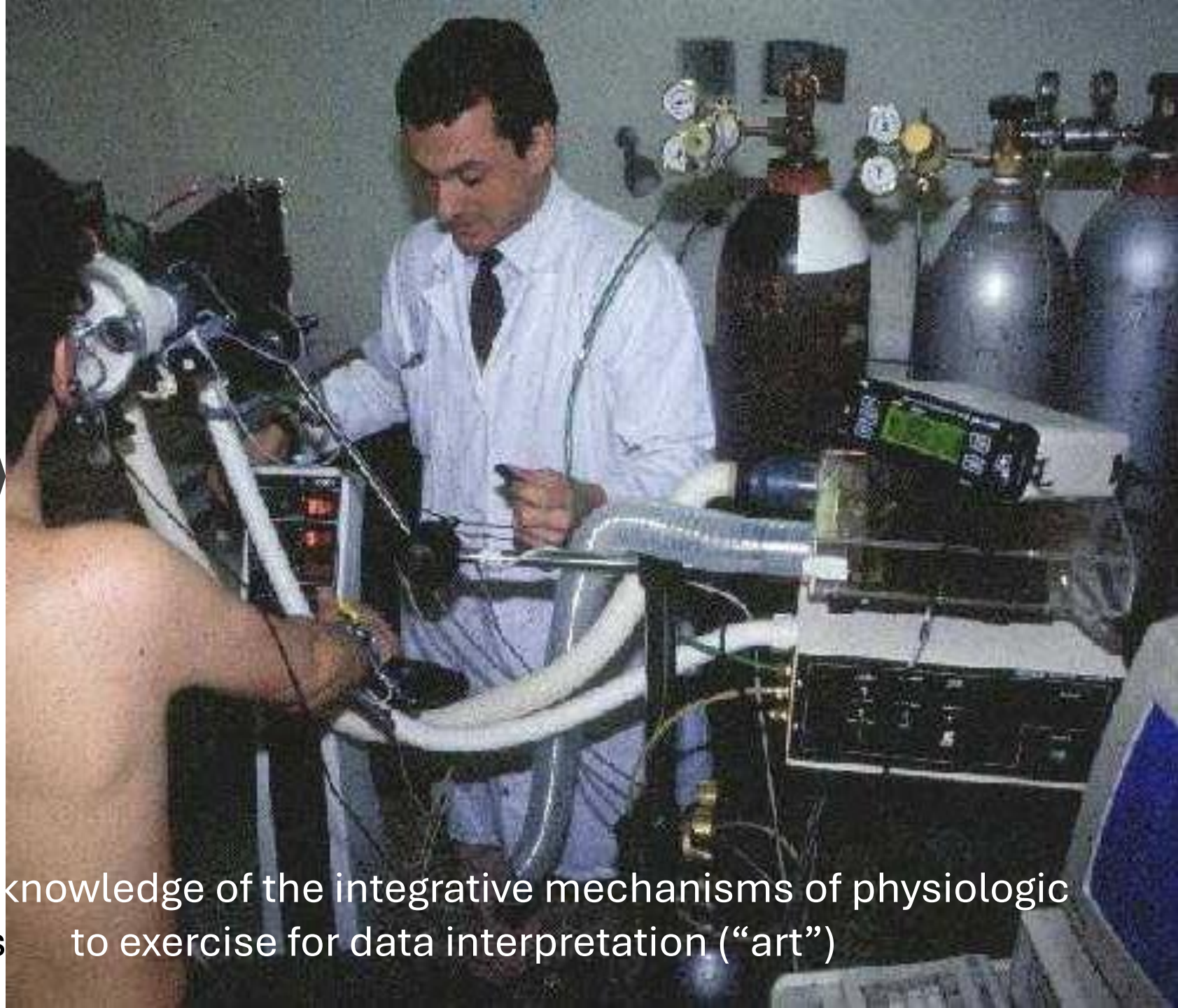


↑	Ventilation
↑	Circulation
↑	Motor force

CPET :

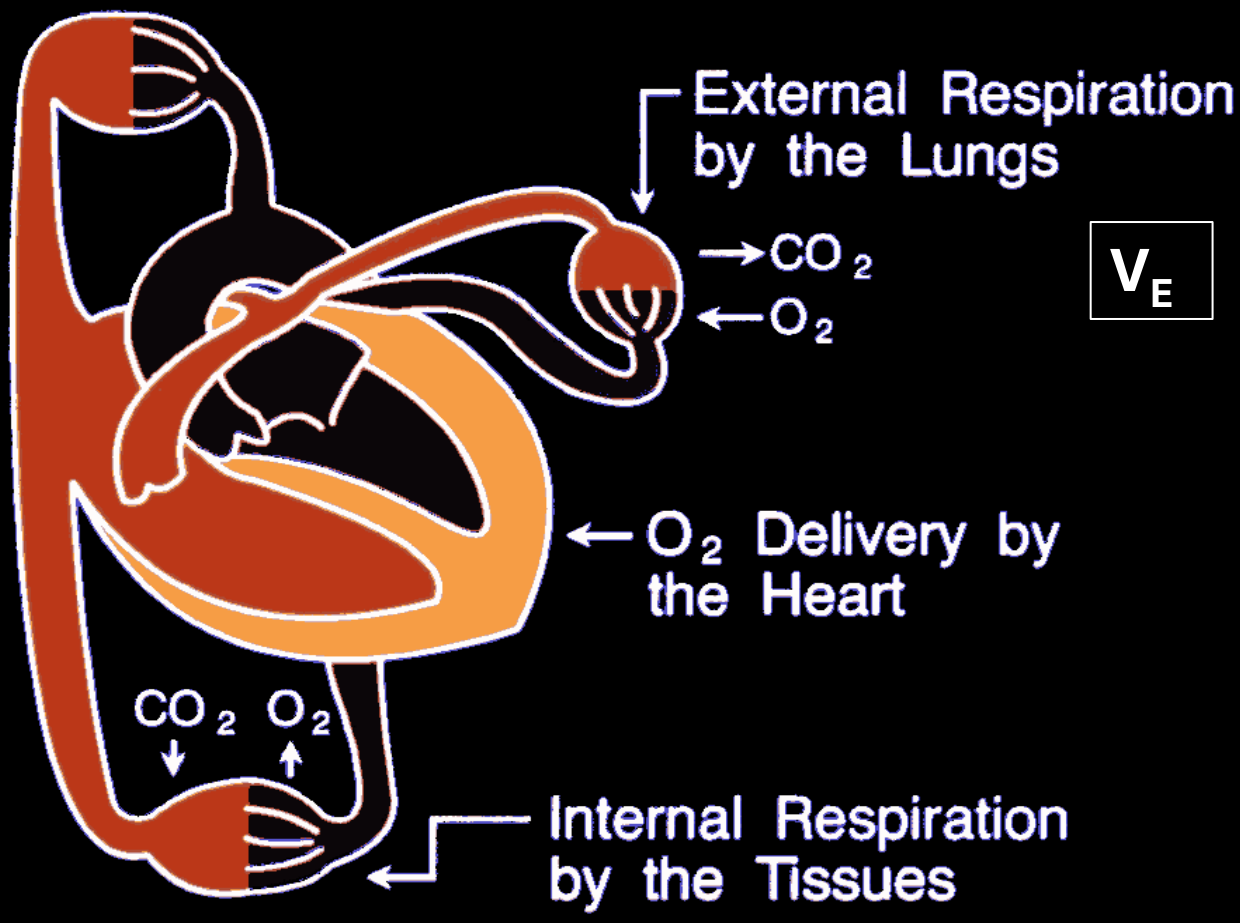
*Why not Used
Often*

Need to have very good knowledge of the integrative mechanisms of physiologic adaptations to exercise for data interpretation (“art”)



Exercise Test: *CPET*

Non-Invasive Estimating Internal Respiration by VO_2 & VCO_2



Exercise - *Lungs / Heart / Circulation / Muscle*

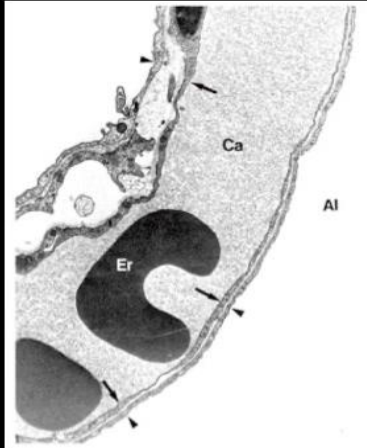
$\dot{V}O_2$

$O_2 \rightarrow$

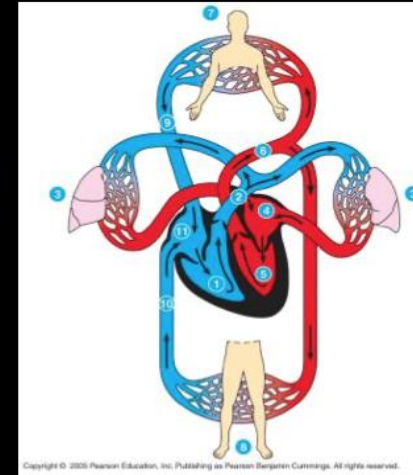
$\dot{Q}O_2$



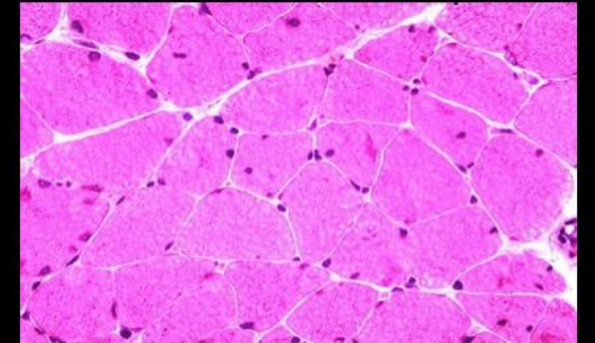
Ventilation



Gas exchange



Oxygen transport



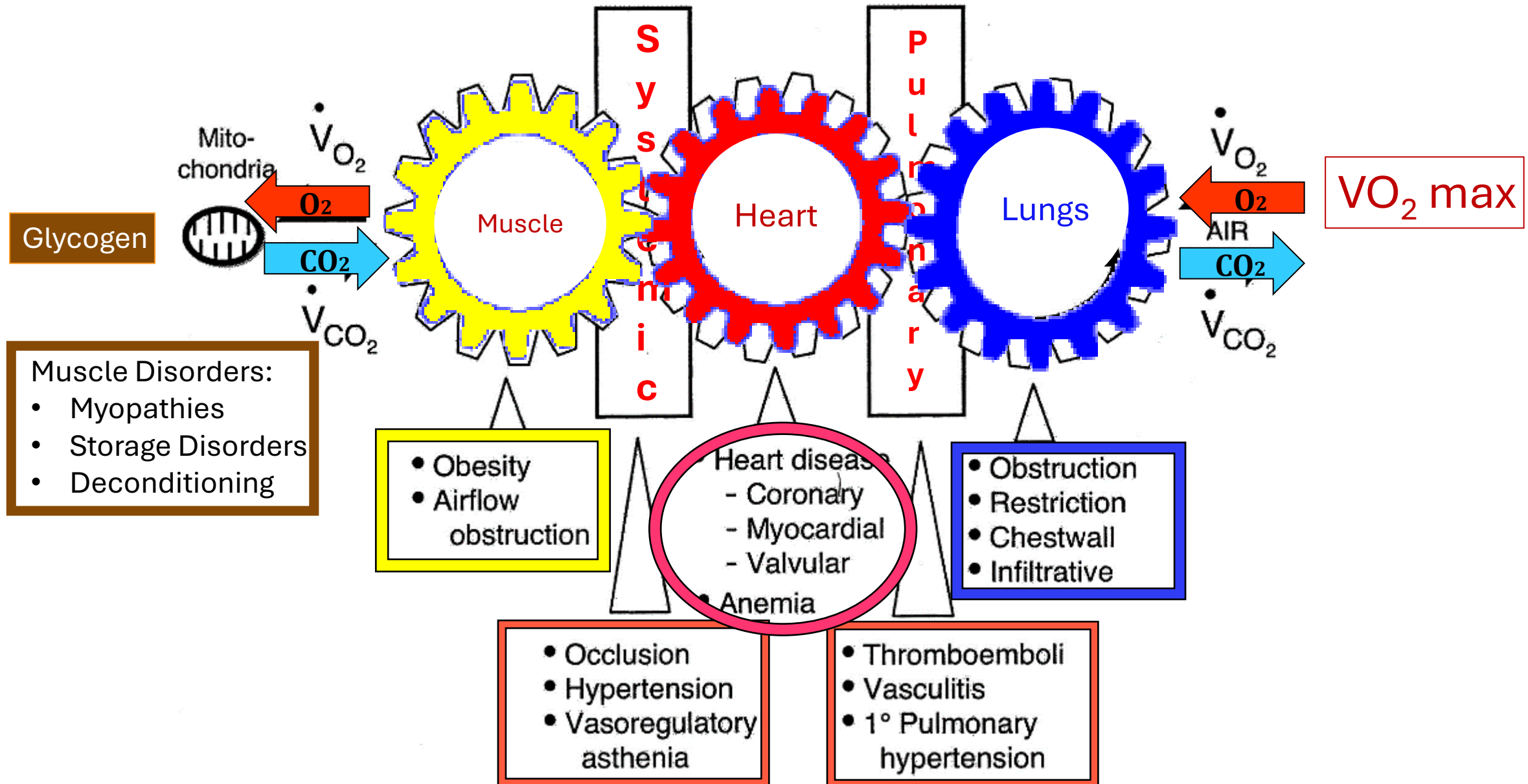
Oxygen extraction

$\dot{V}CO_2$

$\leftarrow CO_2$

$\dot{Q}CO_2$

Limitations to Exercise...





Why CPET Test ???

- Cardiopulmonary measurements obtained at rest may not estimate functional capacity reliably
- Aim to stress the cardio-respiratory system until factor limiting exercise capacity is identified
- By primarily evaluating *peak VO_2 and AT*

Indications for CPET

- Evaluation of dyspnea
 - Distinguish cardiac vs pulmonary vs peripheral limitation vs other
 - Detection of exercise-induced bronchoconstriction
 - Detection of exertional desaturation
- Pulmonary rehabilitation
 - Exercise intensity/prescription
 - Response to participation
- Pre-op evaluation and risk stratification
- Prognostication of life expectancy
- Disability determination
- Fitness evaluation
- Diagnosis
- Assess response to therapy

Exercise Details:		Pred	Rest	Warm up	AT	% Pred	RCP	Max. Load	% Pred	Recovery
Time	[min]	-	00:57	02:50	11:06	-	11:26	13:20	-	17:06
Load	[W]	208	0	0	138	66 %	143	171	82 %	0

Metabolic Response:

V'O2	[L/min]	3.05	0.39	0.67	2.25	74 %	2.43	2.61	86 %	0.70
V'O2/kg	[mL/min/kg]	37.70	4.78	8.32	27.74	74 %	29.97	32.26	86 %	8.60
V'CO2	[L/min]	3.36	0.34	0.61	2.25	67 %	2.54	2.92	87 %	0.74
METS	[]	-	1.4	2.4	7.9	-	8.6	9.2	-	2.4
RER	[]	-	0.87	0.91	1.00	-	1.04	1.12	-	1.06
REE	[kcal/ day]	-	2705	4770	16304	-	17787	19462	-	5104

Ventilatory Response:

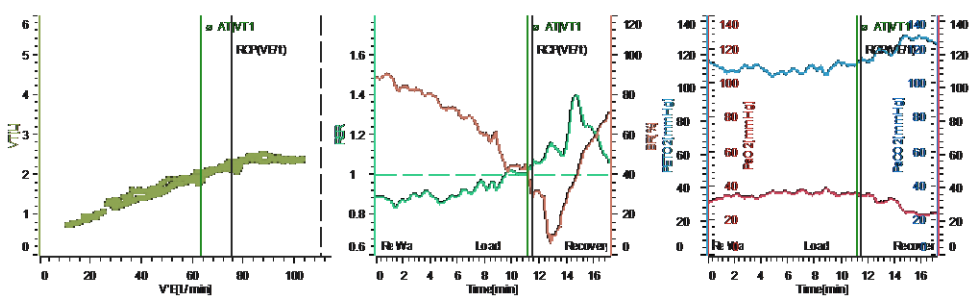
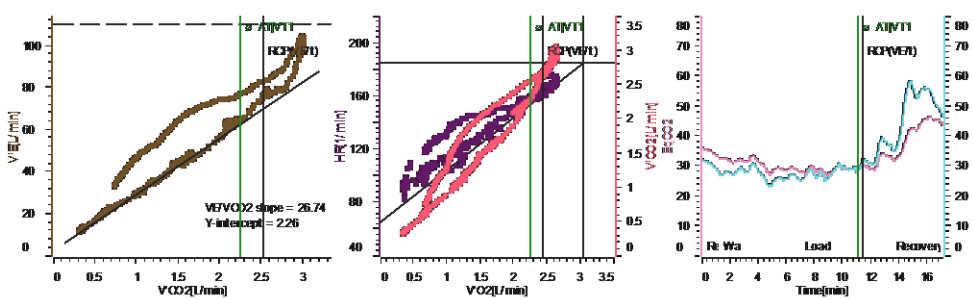
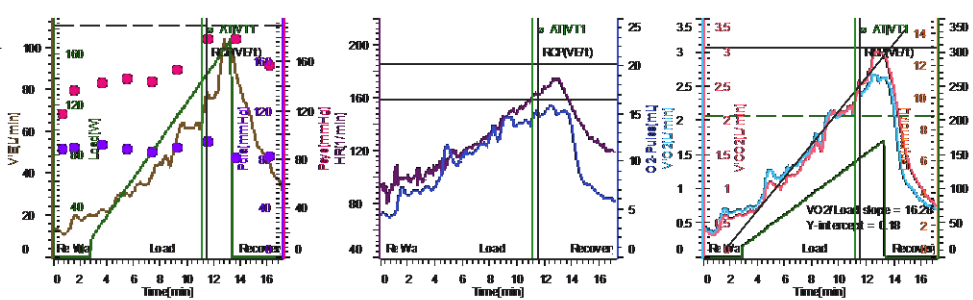
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VT	[L]	0.58	0.71	0.86	2.04	353 %	2.12	2.29	396 %	1.20
BF	[1/min]	20	18	24	33	167 %	36	42	209 %	28
BR	[%]	28.0	89.7	81.9	42.8	153 %	32.2	13.0	46 %	70.7
Vd%VT	[%]	-	10.82	11.98	15.17	-	16.37	16.68	-	15.21

Cardiovascular Response:

HR	[1/min]	185	91	103	158	85 %	162	167	90 %	119
O2-Pulse	[mL]	16.5	4.4	6.8	14.4	87 %	15.2	15.2	92 %	5.8
HRR	[1/min]	-	94	82	27	-	23	18	-	66
V'CO2	[L/min]	3.36	0.34	0.61	2.25	67 %	2.54	2.92	87 %	0.74

Gas Exchange:

EqO2	[]	-	29.3	29.6	28.1	-	30.8	36.8	-	46.4
EqCO2	[]	-	33.6	32.6	28.1	-	29.5	32.8	-	43.6
PETCO2	[mmHg]	-	34	34	37	-	36	32	-	25
PETO2	[mmHg]	-	112	114	113	-	116	121	-	126

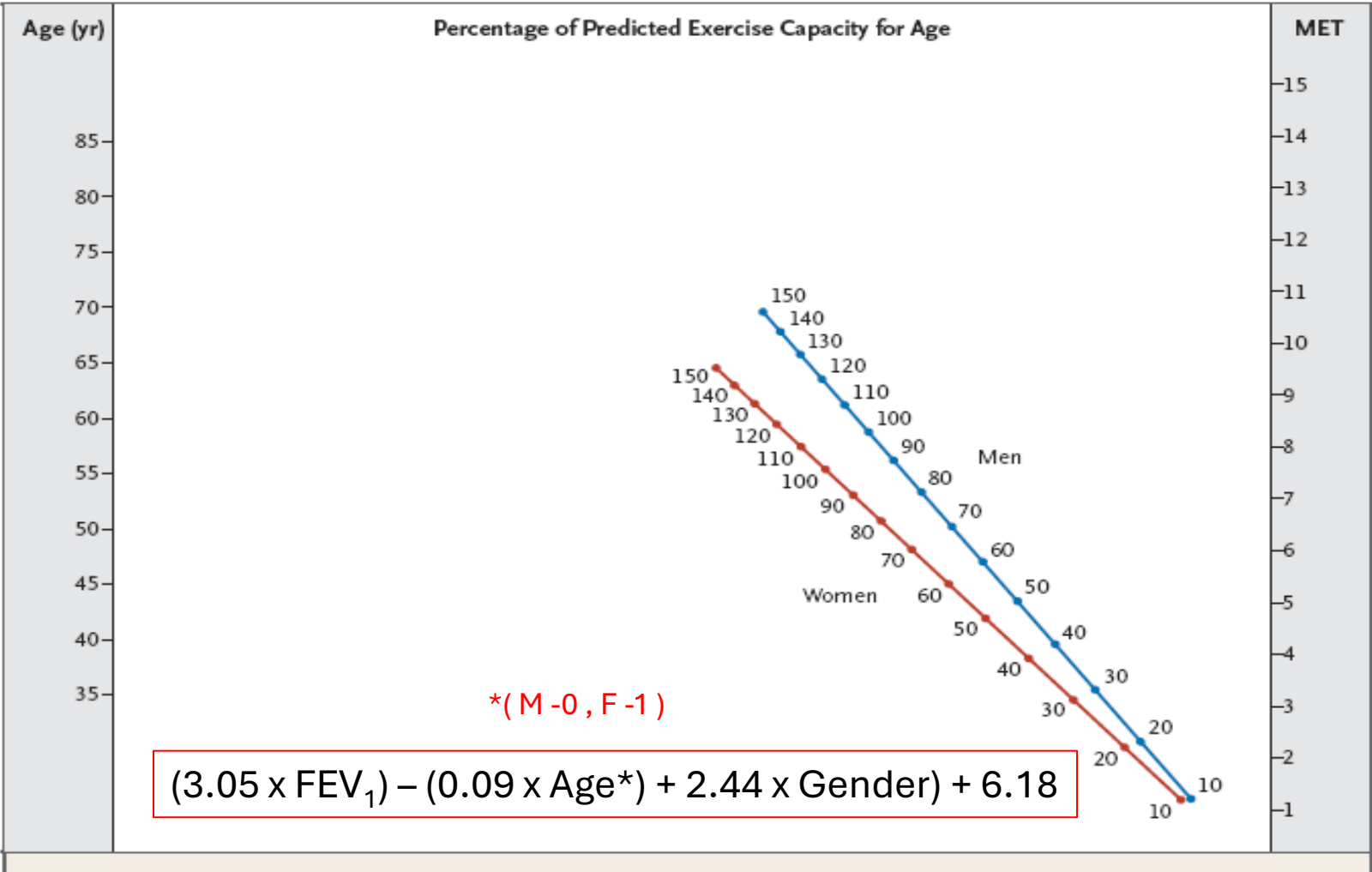


Step/Stage	Time [mm:ss]	Load [W]	HR [1/min]	BP [mmHg]	ST 1 J40 [mm]/(mV/s)	Borg VES [count]	SpO2 [%]
Sitting	01:01	0	91	118/76	0.3/0.4	- 0	98
Warm-up	02:55	0	98	126/78	0.4/0.5	- 0	98
Step 1	01:00 (03:55)	30	102	136/81	0.4/0.6	- 0	98
Step 2	02:00 (04:55)	45	109	142/83	0.3/0.4	- 0	98
Step 3	03:00 (05:55)	60	115	150/84	0.3/0.4	- 0	98
Step 4	04:00 (06:55)	75	123	158/86	0.2/0.3	- 0	98
Step 5	05:00 (07:55)	90	132	162/88	0.2/0.3	- 0	99
Step 6	06:00 (08:55)	105	142	171/90	0.1/0.6	- 0	99
Step 7	07:00 (09:55)	120	148	176/91	0.1/0.6	- 0	98
Step 8	08:00 (10:55)	135	157	185/93	0.2/0.6	- 0	98
Step 9	09:00 (11:55)	150	165	192/94	0.1/0.7	- 0	97
Step 10	10:00 (12:55)	165	174	196/95	0.1/0.9	- 0	97
Max Load	10:27 (13:22)	171	182	202/97	0.1/1.0	- 0	97
Recovery	01:00 (14:22)	0	152	188/90	0.4/1.4	- 0	97
STmax	14:40	0	139	-/-	0.5/1.5	- -	-
Recovery	02:00 (15:22)	0	130	162/84	0.4/1.2	- 0	98
Recovery	03:00 (16:22)	0	125	155/80	0.4/1.0	- 0	98
EoE	03:45 (17:07)	0	119	146/79	0.5/1.2	- 0	98

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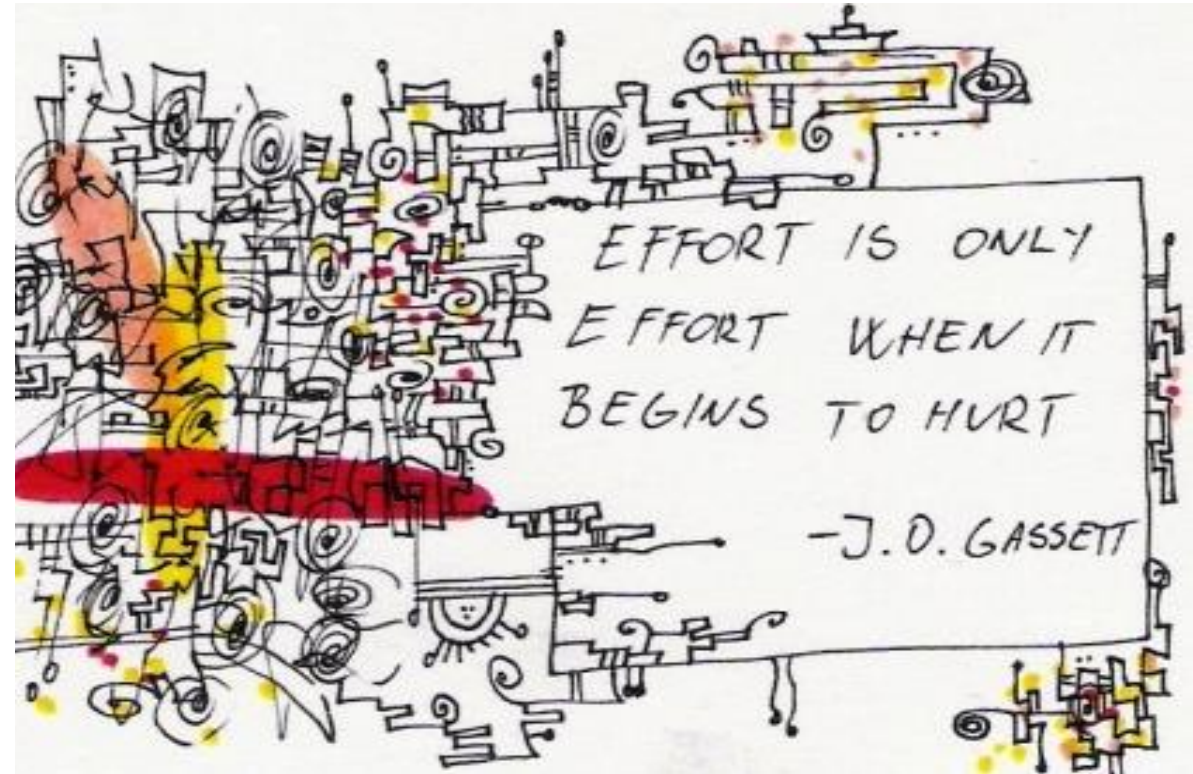
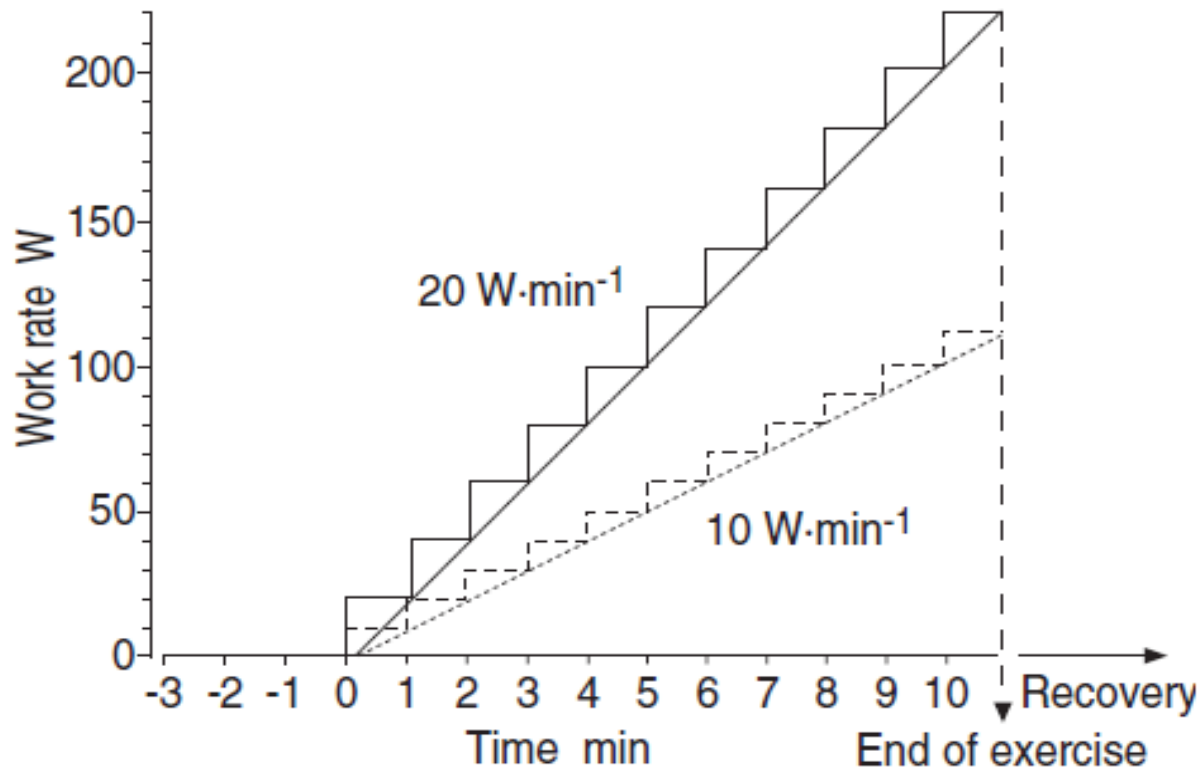
Exercise :
*Load to be
Given*

Gulati M, N Engl J Med 2005

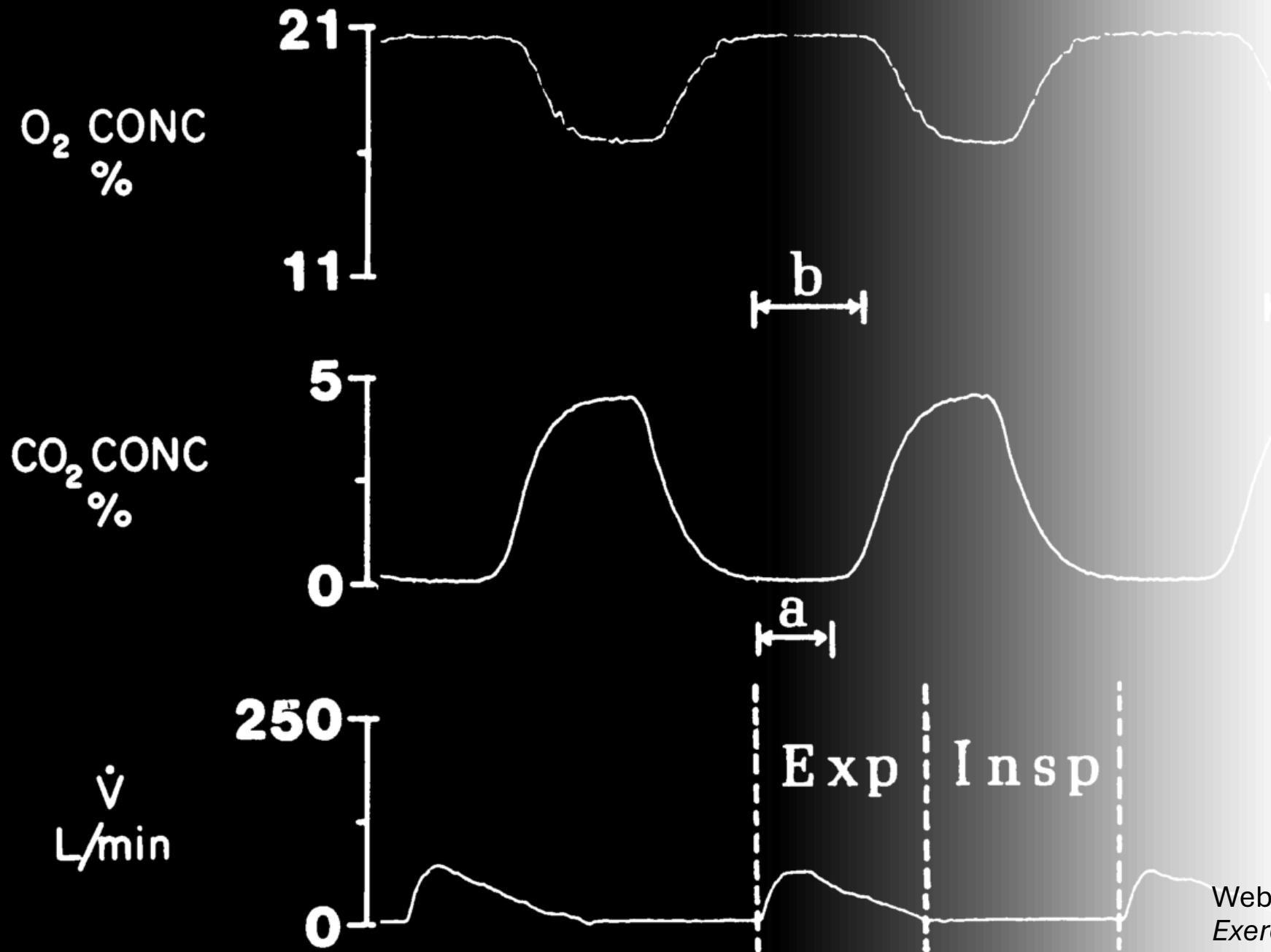


Exercise Protocol : To Reach Limit

... *till Exhaustion*



Work : To do Maximum - Incremental !



CPET : Breath-by- Breath Respiratory Gas Exchange

Weber KT & Janicki JS. In: *Cardiopulmonary Exercise Testing*. Philadelphia: Saunders. 1986

Optimal Exercise Test

- Typically, ≥ 2 or of the following criteria to be met :
 - RER > 1.1
 - ± 10 beats / min predicted maximum HR
 - RPE > 17 (6-20 rating scale)



Exercise Details:

Pred Rest Warm up AT % Pred RCP Max. Load % Pred Recovery

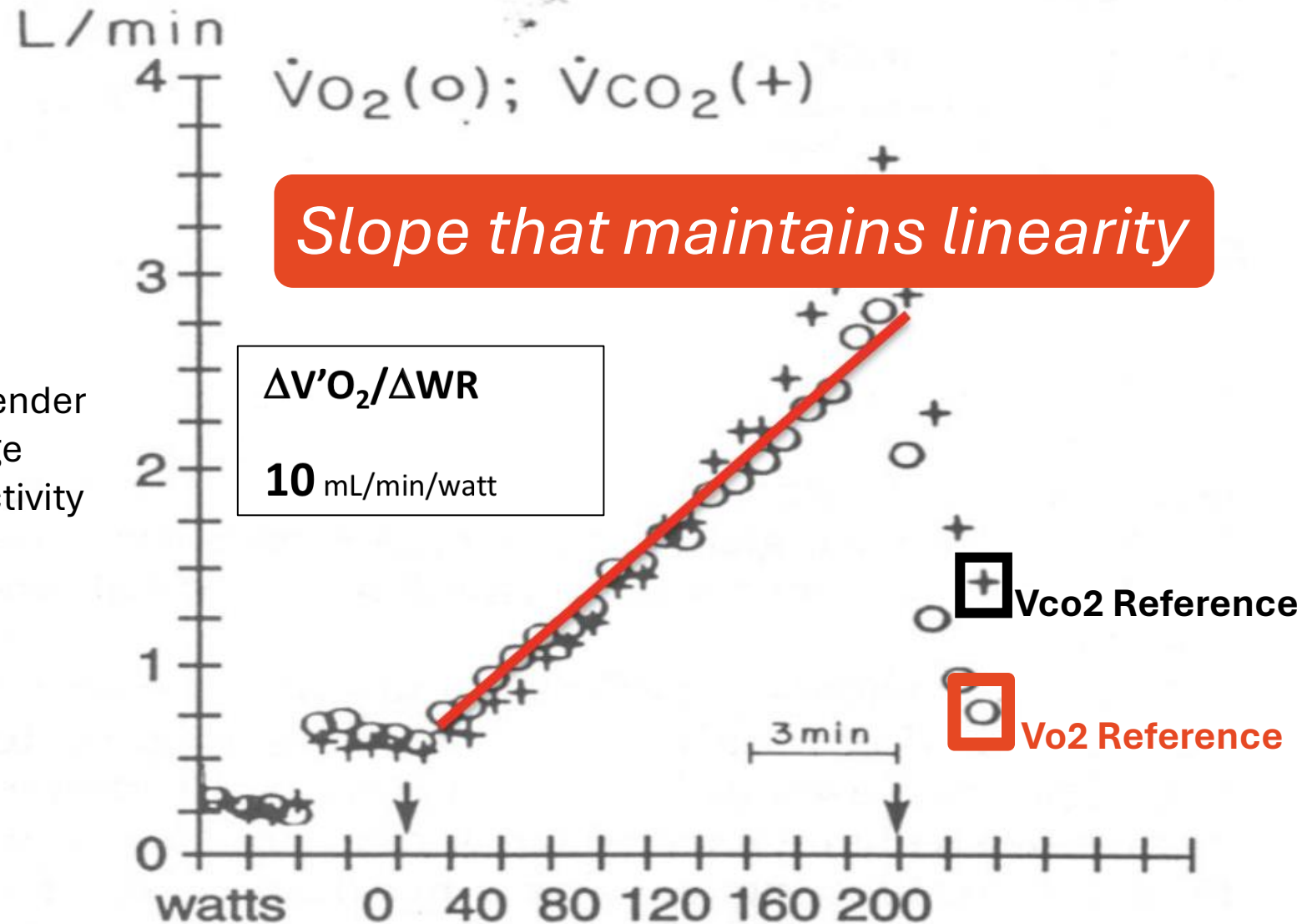
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VO₂max

- Gender
- Age
- Activity

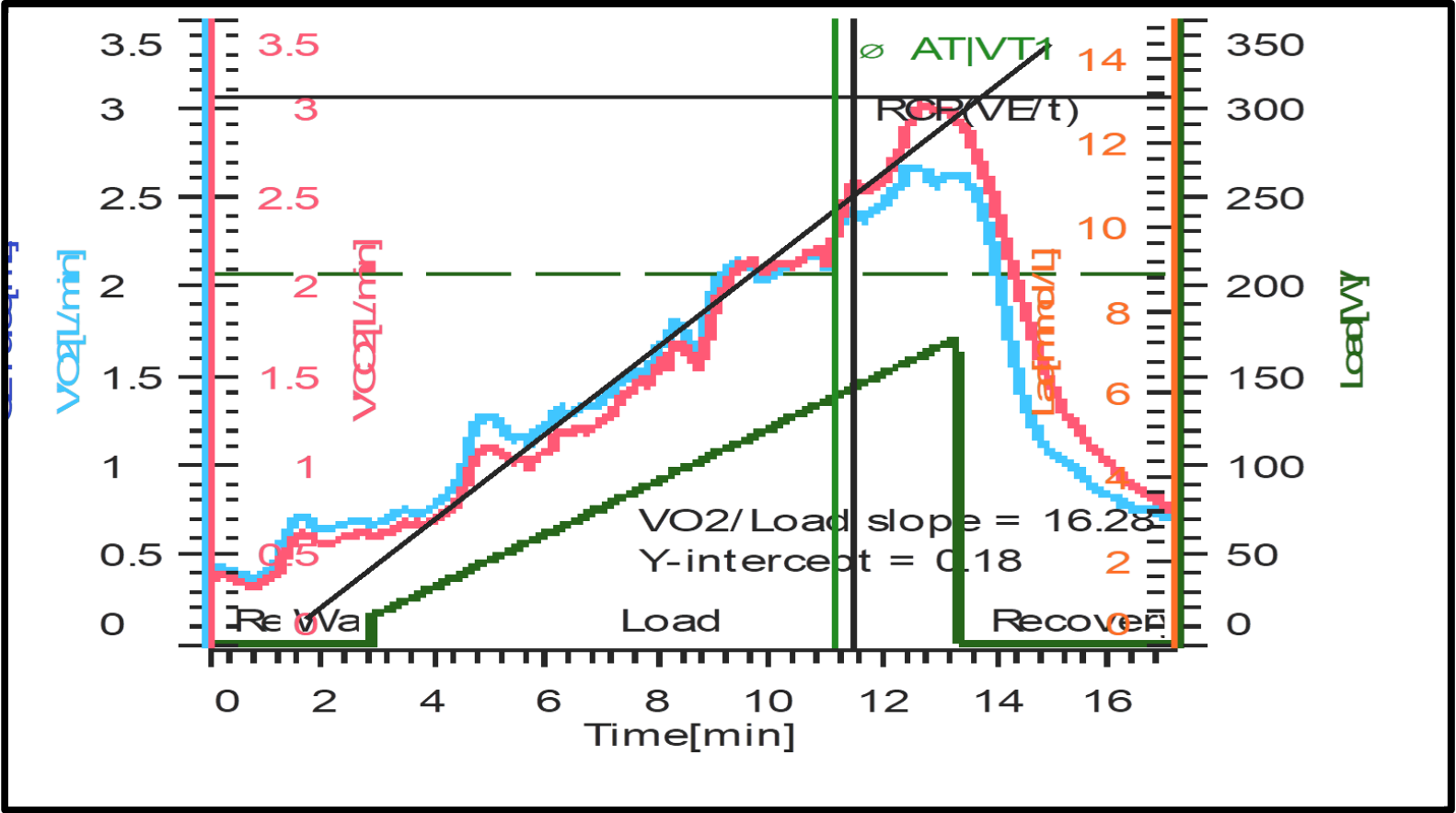
$$VO_2 \text{ max} = 15 \times (\text{HR max} / \text{HR rest})$$



➤ CPET is the MOST Direct test to determine $Vo_2 \text{ max}$

Metabolic Response

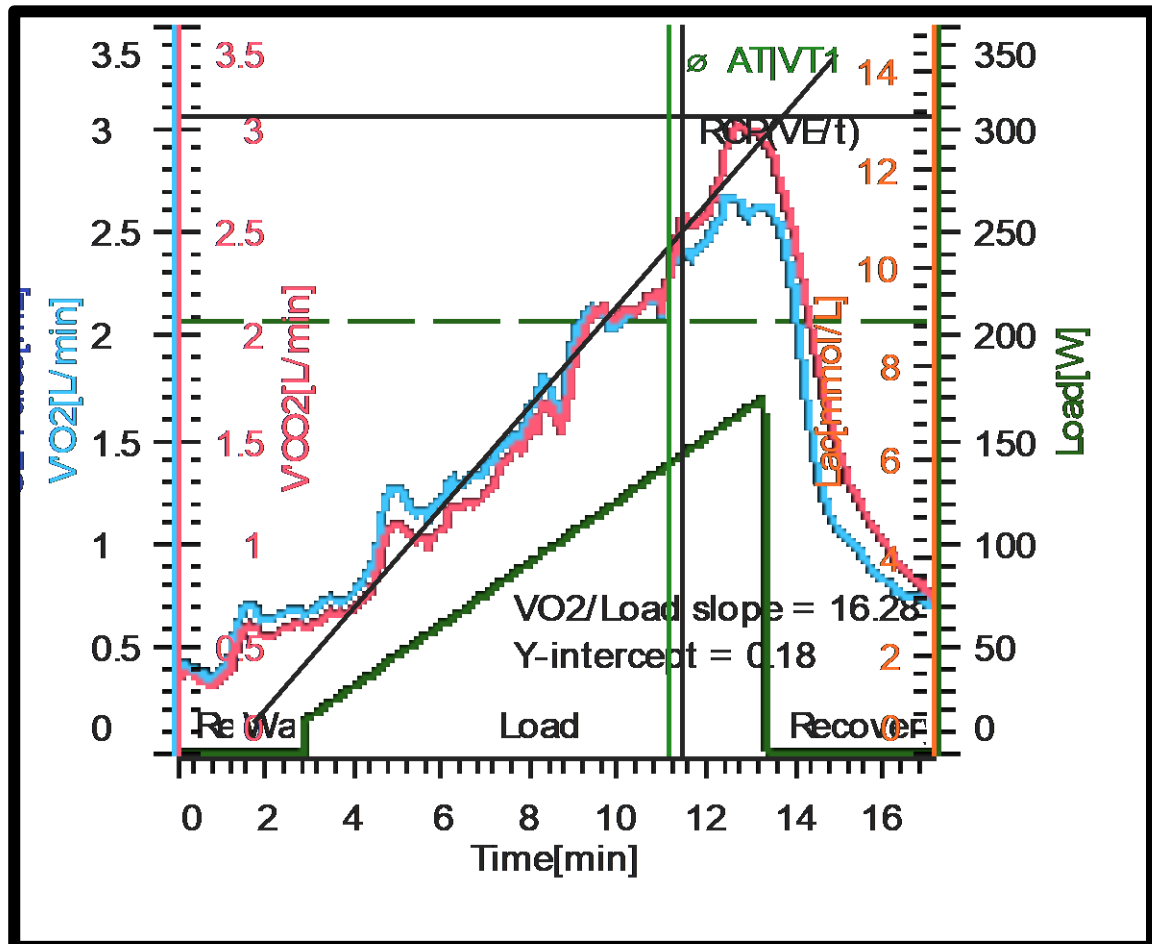
VO₂ – WR Slopes



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$V_{E}CO_2$

Anaerobic
Threshold



Exercise Details:

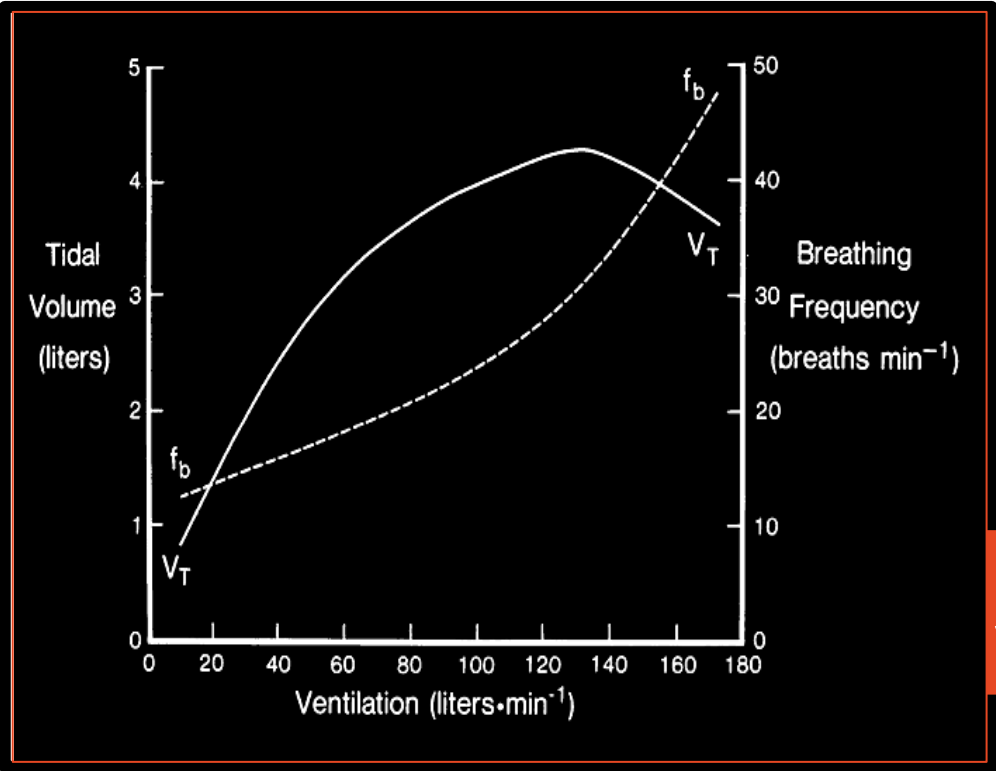
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Ventilatory Response

$V_E - T$ and V_T/RR Slopes



Ventilation =
Volume x Respiratory Rate

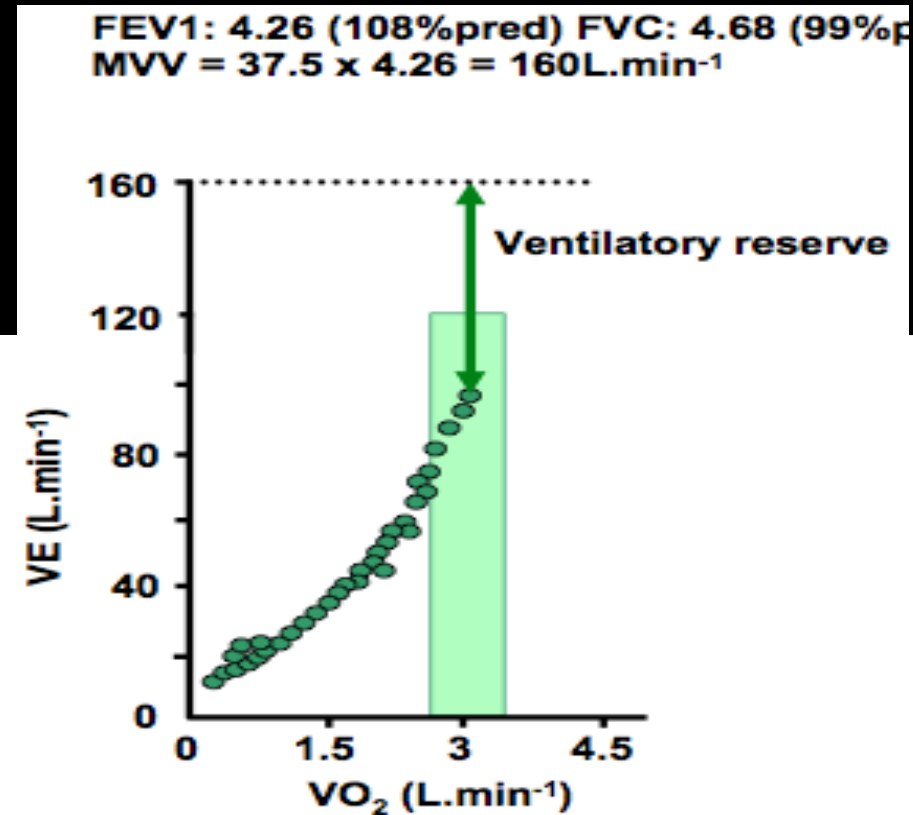
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Vd%VT	[%]	-	10.82	11.98	15.17	-	16.37	16.68	-	15.21

Concept of Breathing Reserve : BR

MVV – VE max

$$BR = (MVV - V_{E \max} / MVV) \times 100$$

Normal - 20-30 %
Typically < 15%
considered low

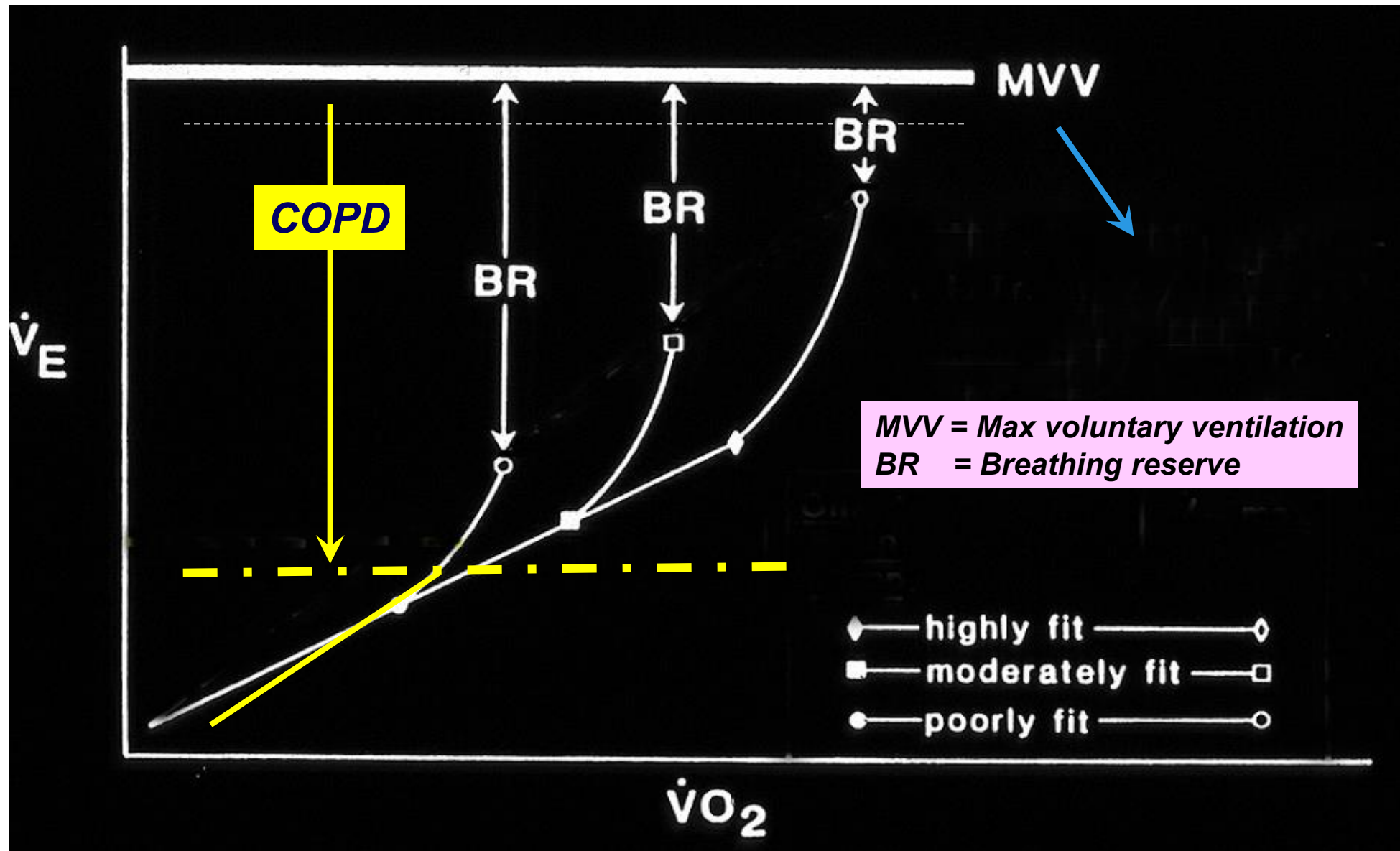


Exercise Details:

Pred Rest Warm up AT % Pred RCP Max. Load % Pred Recovery

Ventilatory Response:

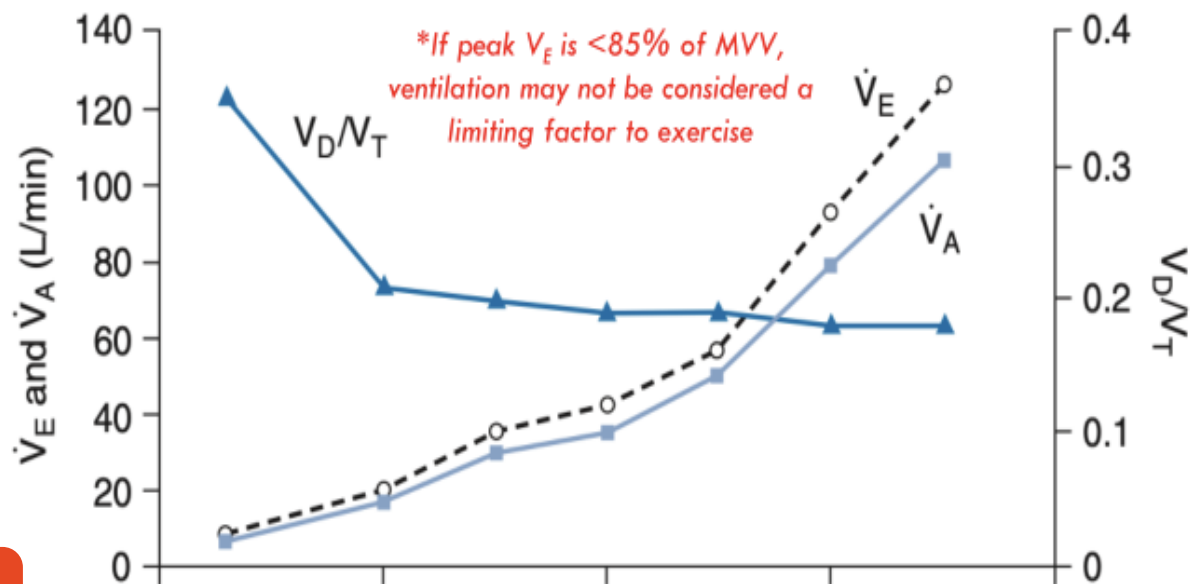
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Modified from Whipp BJ, Pardy R. In: *Hbk Physiol, Resp (Pulmonary Mechanics)*.
Eds: Macklem P, Mead J. Washington DC: Amer Physiol Soc, pp 605-629, 1986.



$$V_A = V_E - V_D$$



Increase or does not decrease with exercise : Poor gas exchange

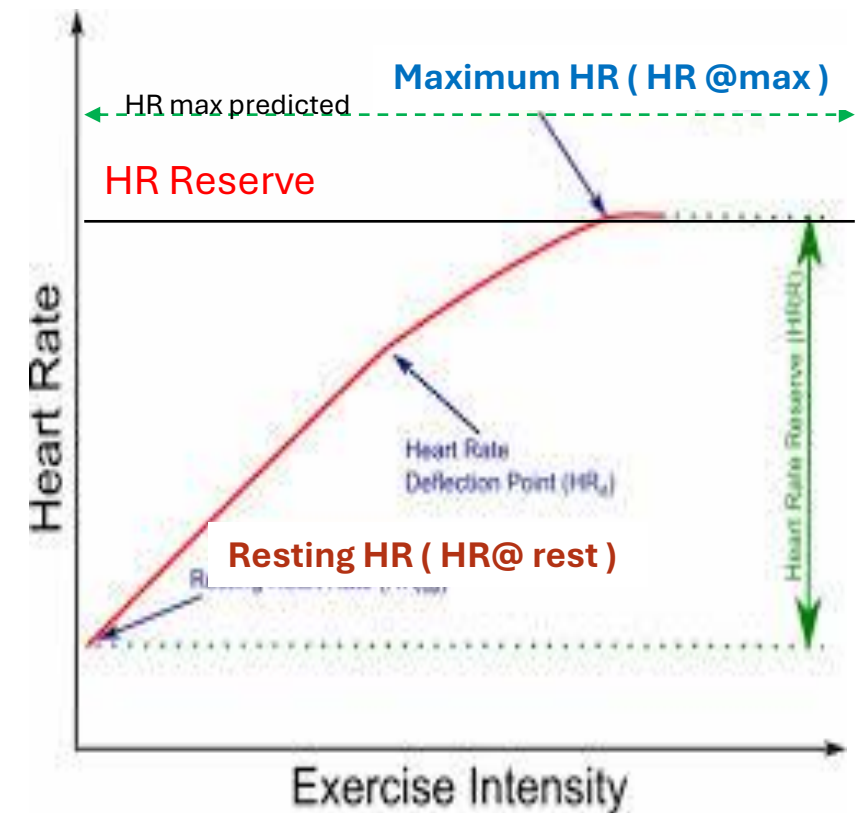
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Cardiovascular Response

Heart Rate

Heart Rate Reserve < 15 beats/min is ~ Normal

Predicted max HR = 220- Age



Exercise Details:

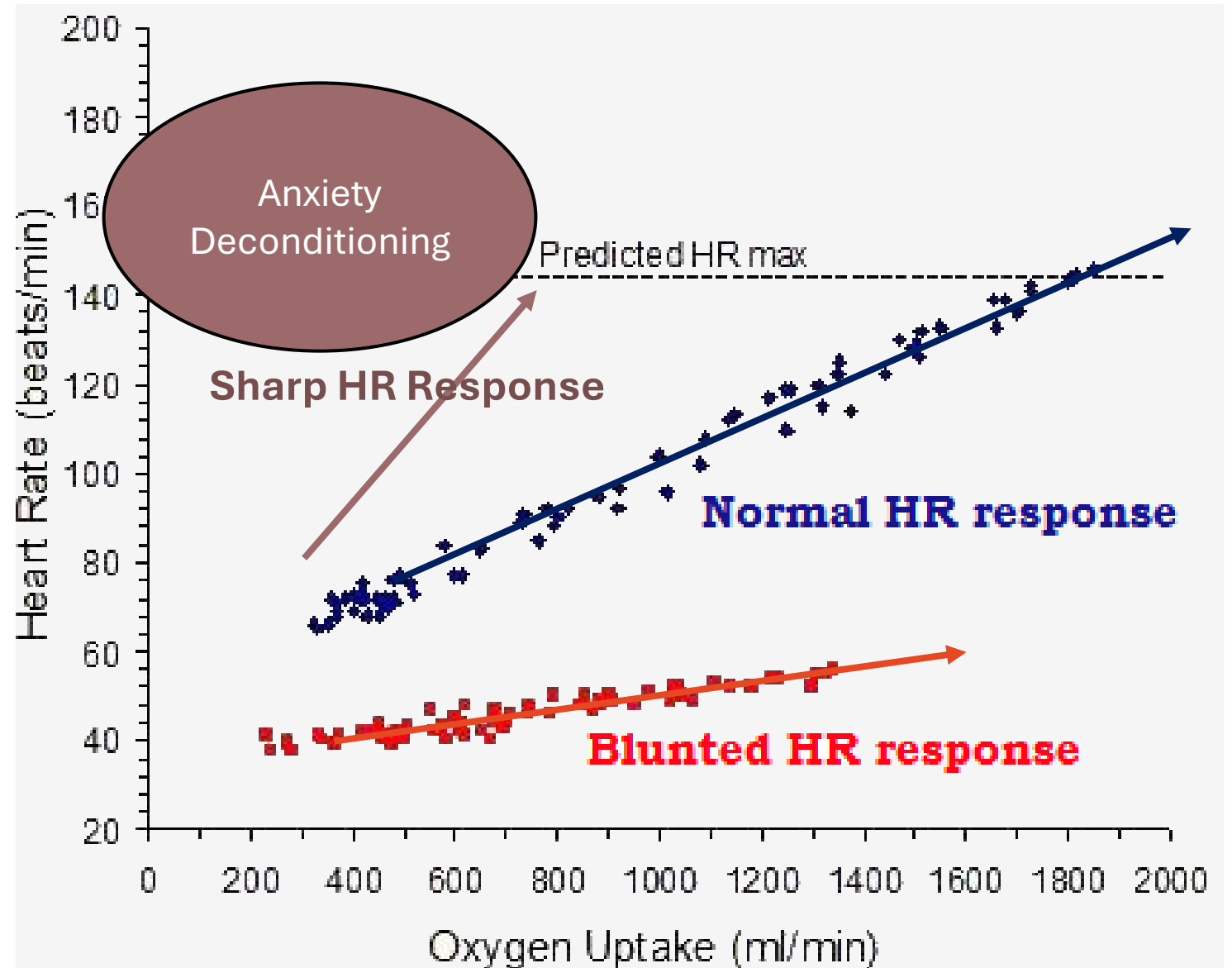
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Cardiovascular Response:

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HRR	[1/min]	-	94	82	27	-	23	18	-	66
V' CO2	[L/min]	3.36	0.34	0.61	2.25	67 %	2.54	2.92	87 %	0.74

Abnormal HR Response : *Sharp vs Blunt*

- Drugs : Ca channel or Beta blockers
- Heart Failure & LVH
- CAD
- Autonomic dysfunction
- SA Node disease
- Elderly : Atherosclerosis



Cardiovascular Response

Oxygen Pulse

$$VO_2 / HR = O_2 \text{ Pulse}$$

Amount of oxygen consumed by the body with each heartbeat and is often used as a surrogate for stroke volume and peripheral oxygen extraction

Surrogate
for Stroke
Volume

$$VO_2 = HR \cdot SV(CaO_2 - CvO_2)$$

$$VO_2/HR = SV(CaO_2 - CvO_2)$$

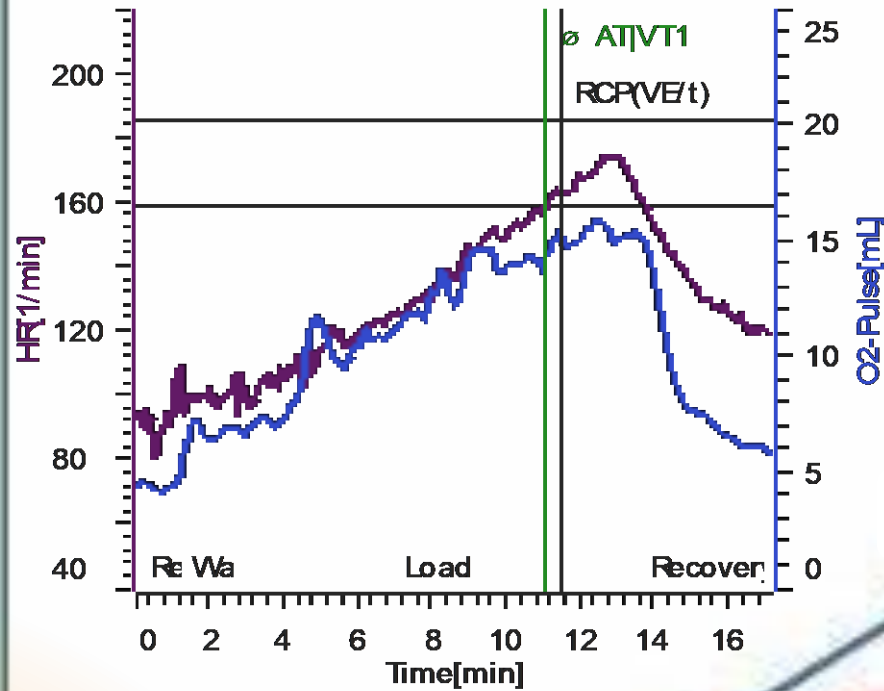
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Oxygen pulse (ml/beat)



↑ Stroke Volume

Normal response

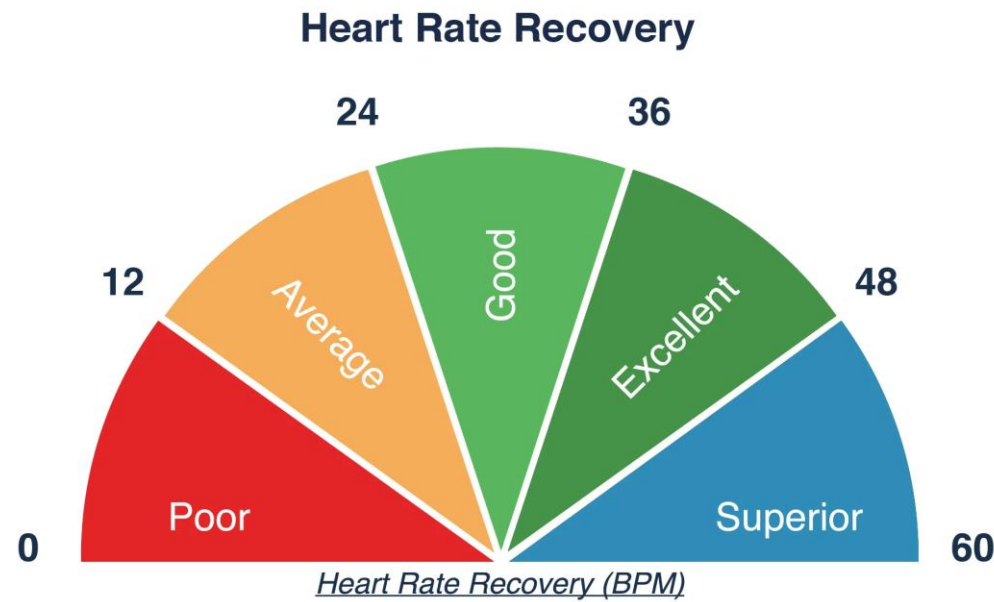
↑ Oxygen Extraction

O₂ pulse normally increases with incremental exercise due to increases in both SV and O₂ extraction

Abnormal responses

Early Plateau or late decrease seen in Diastolic dysfunction

Heart Rate Recovery : *HRR*



- Time to recover HR to baseline after peak exercise
- Impaired LV systolic dysfunction, myocardial ischemia and predicts mortality
- Normal = 15-20 / min : < 12 is abnormal

Exercise Details:

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Ventilatory Equivalents

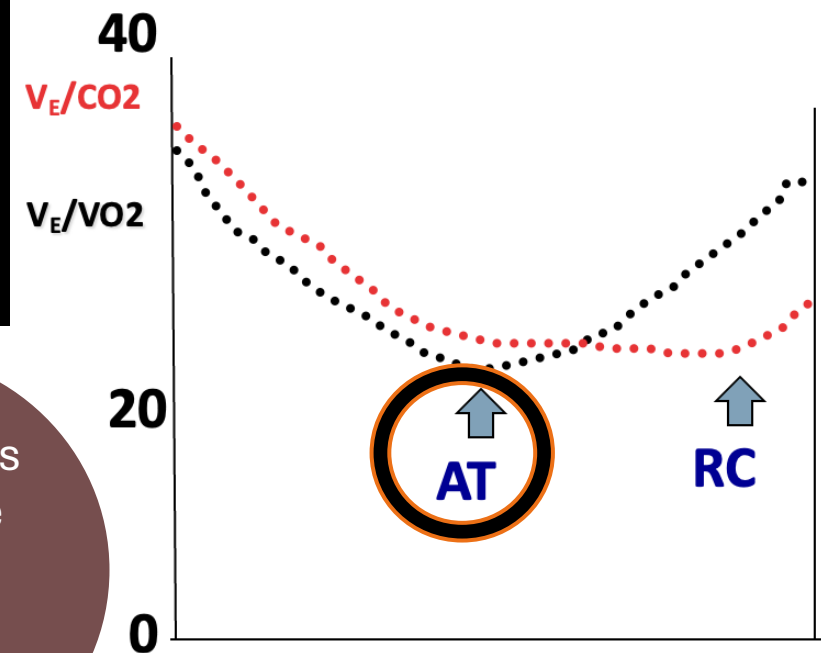
Oxygen & Carbon Dioxide

How many L of air we need to breath to exchange 1 L of gas : V_E/VO_2 , V_E/VCO_2

Abnormally High:

- Hyperventilation
- Increase dead Space

Lower values on Exercise indicate better efficiency



VE/VO_2 @ AT: 26.5 (22.1 – 30.9)

VE/VCO_2 @ AT: 29.1 (24.8 – 33.4)

Exercise Details:

Pred

Rest

Warm up

AT

% Pred

RCP

Max. Load

% Pred

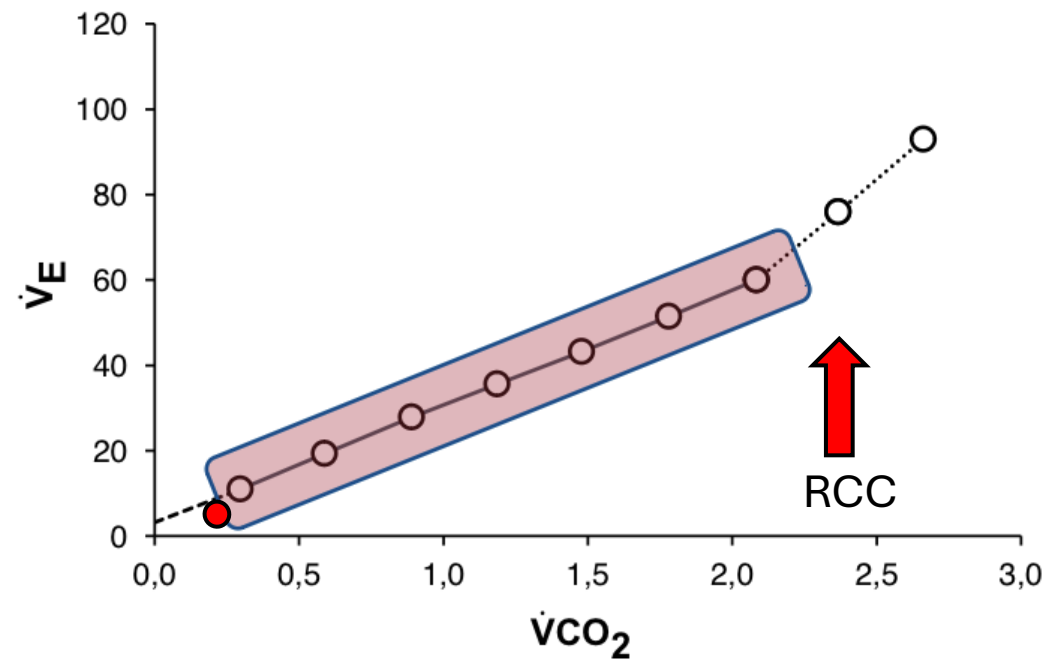
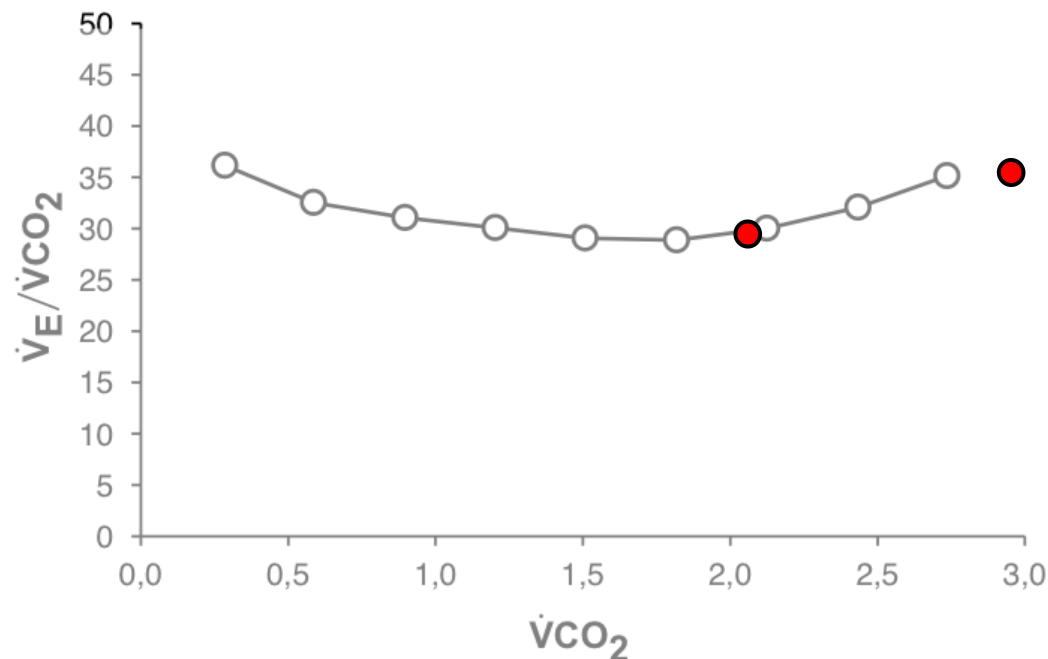
Recovery

Gas Exchange:

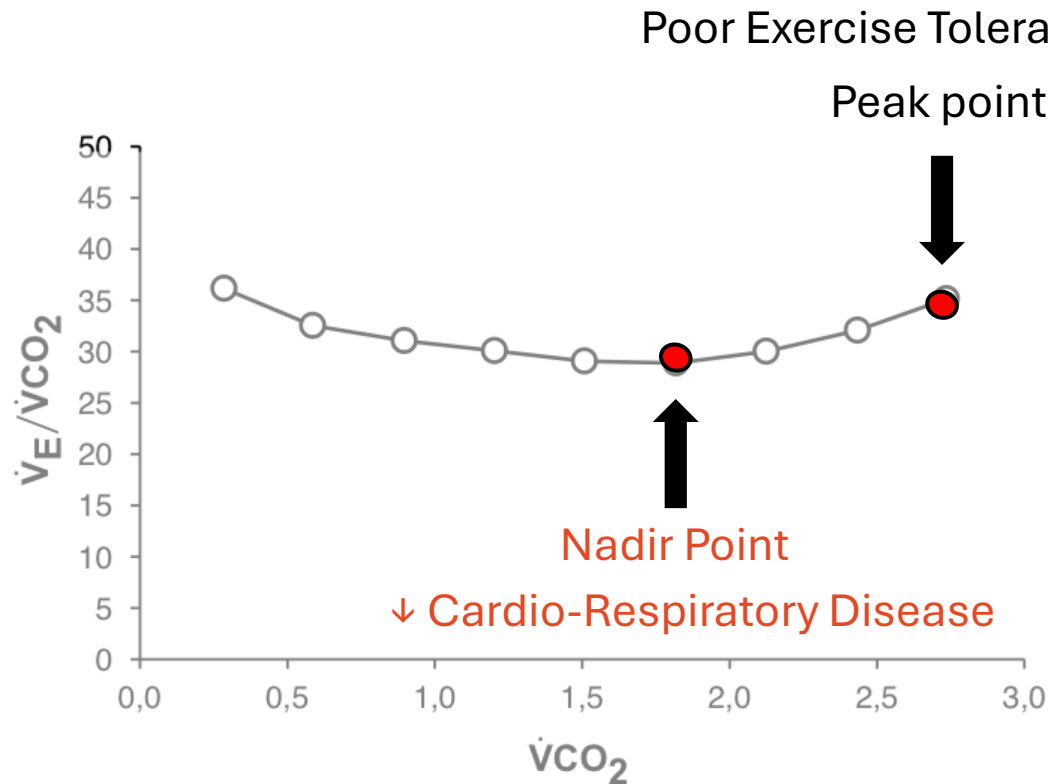
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$\dot{V}_E/\dot{V}_{CO_2}$: Ventilatory Efficiency

1. $\dot{V}_E/\dot{V}_{CO_2}$ nadir : Lowest prior to respiratory compensation point, High in Cardio-respiratory disease
2. $\dot{V}_E/\dot{V}_{CO_2}$ at peak exercise : In poor exercise tolerance - nadir & peak are similar ? unable to exercise
3. $\dot{V}_E$ by $\dot{V}_{CO_2}$ slope : Most robust indicator of V efficiency In the absence of altered ventilatory mechanics-COPD
4. $\dot{V}_E$ by $\dot{V}_{CO_2}$ y-intercept : Elevated increase in $\dot{V}_E$ for a given $\dot{V}_{CO_2}$, Useful for patients terminating CPET early



$\dot{V}_E / \dot{V}_{CO_2}$: Ventilatory Efficiency

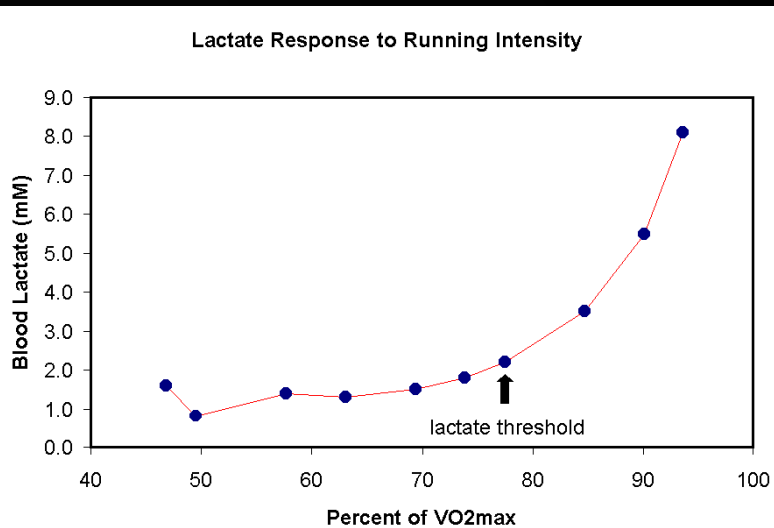


In poor exercise tolerance - nadir & peak are similar ? unable to exercise after AT

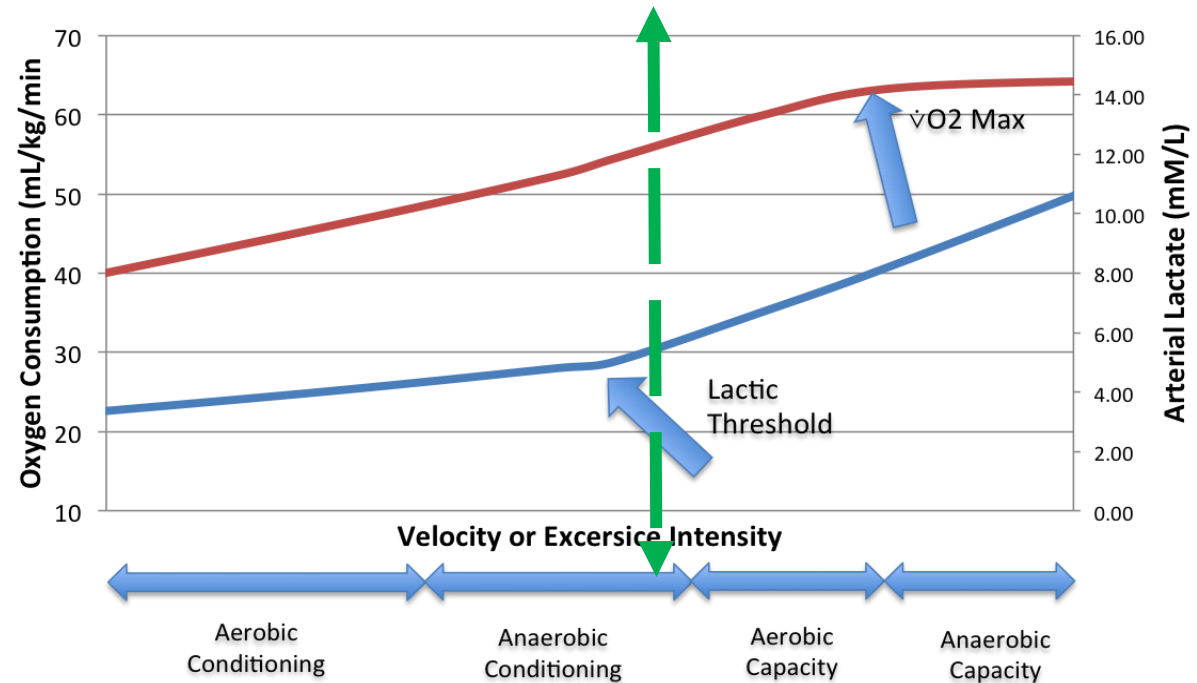
Lowest prior to respiratory compensation point, High in Cardio-respiratory disease

Concept of Anaerobic Threshold & Lactate Threshold

- ❖ Point at which there is switch from aerobic metabolism to anaerobic metabolism due to blood flow limitation to exercising muscles



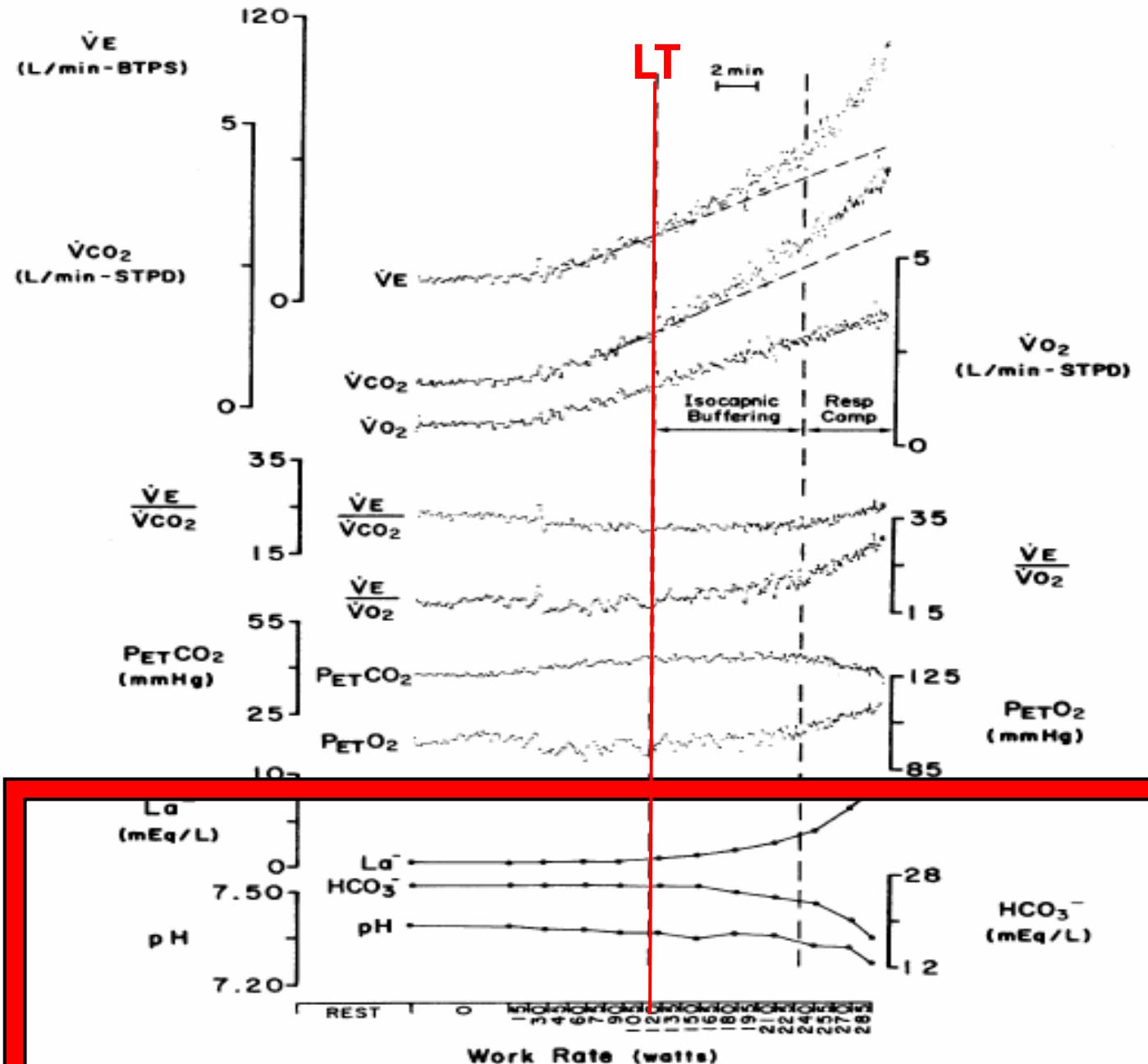
Arterial Lactate measurements



Physiological Responses at AT

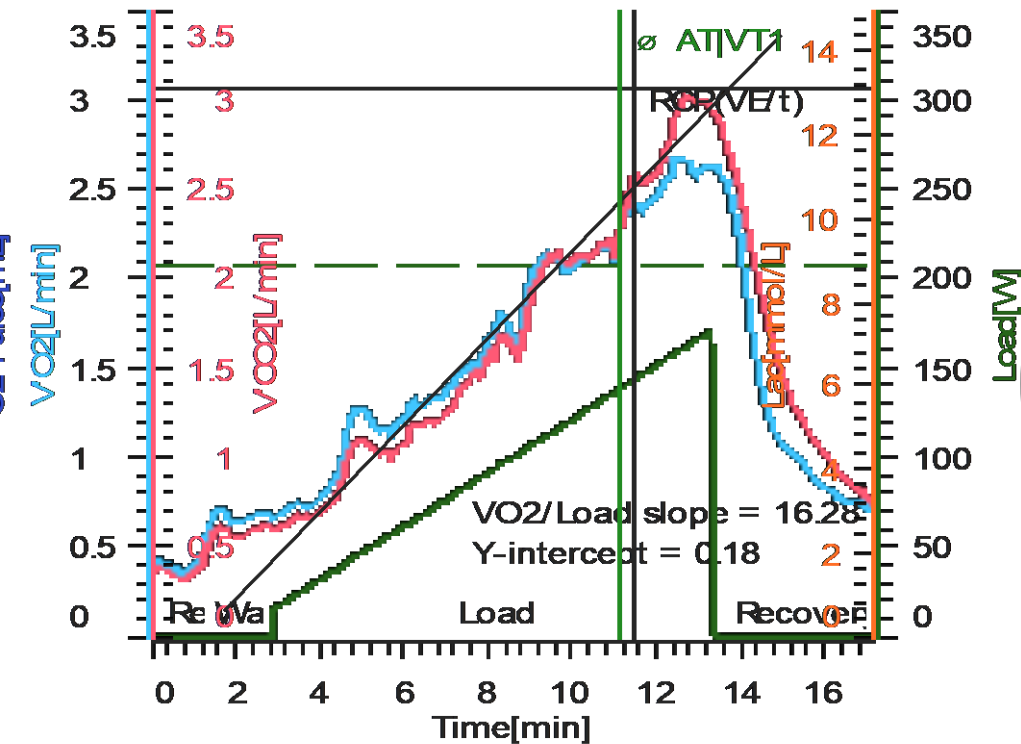
LT & AT are used interchangeably in Exercise Test

- Rise of $\dot{V}_E$ slope
- Rise of $\dot{V}CO_2$ slope
- Rise of $\dot{V}O_2$ slope



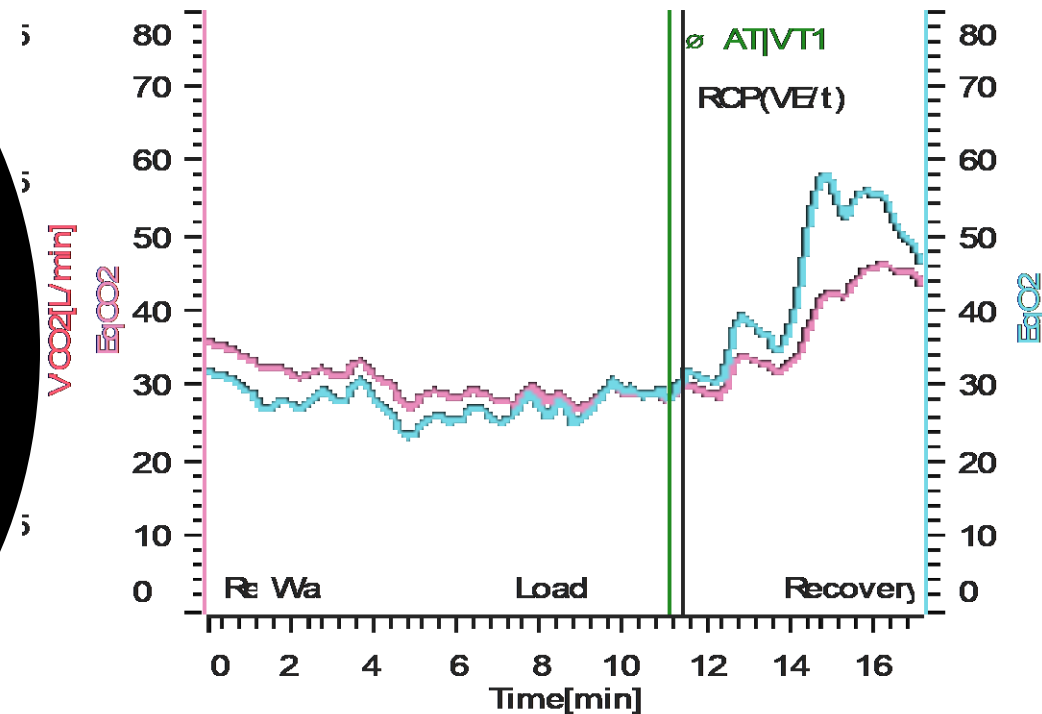
Anaerobic Threshold

Normally – 50-85% and 40% is the generally accepted LLN used clinically

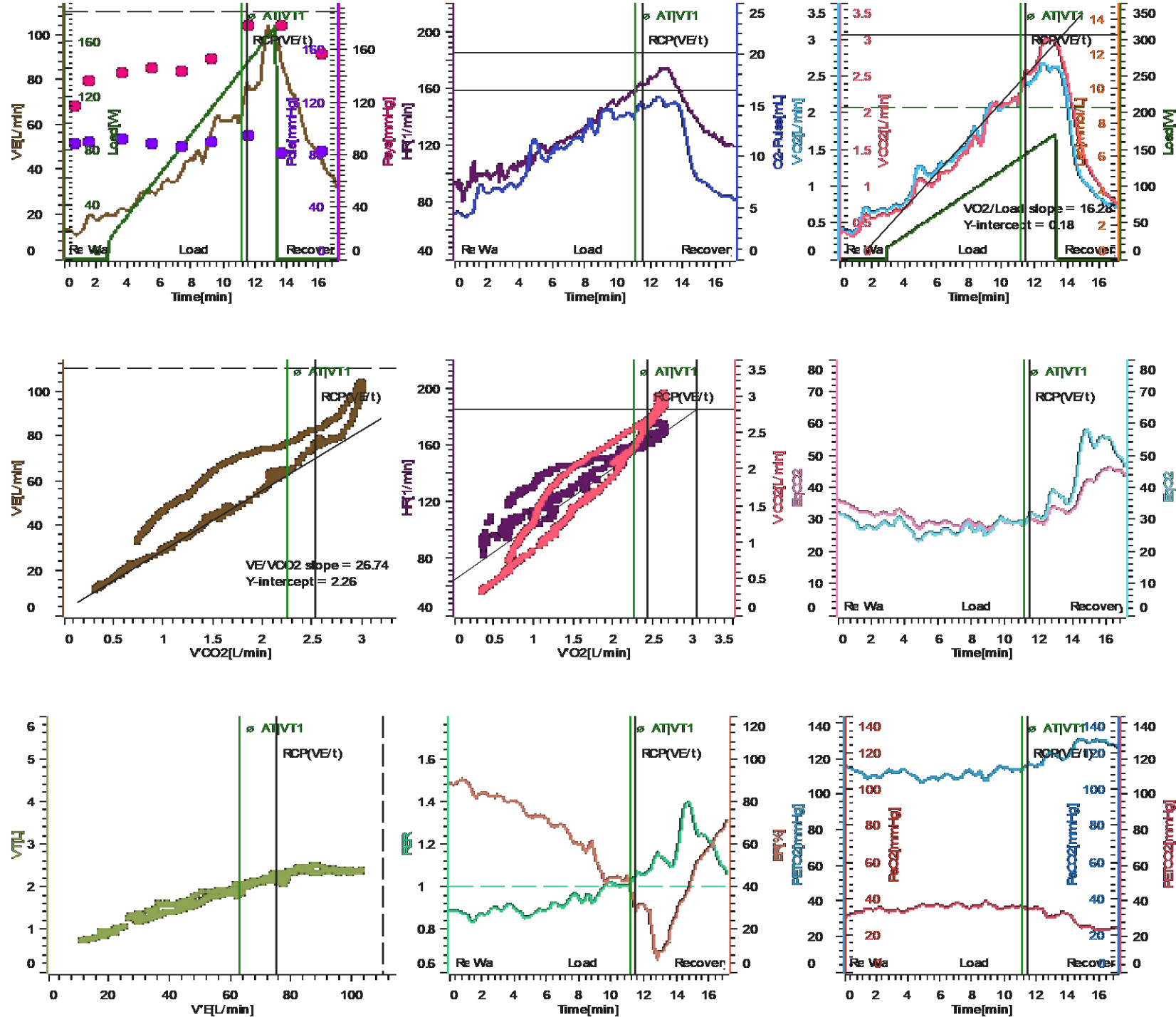


Not Identifiable

- COPD
- DCMP on B blocker
- Elderly
- Obese



Wasserman 9-Panel Plot



Interpret CPET Results: *Putting it all together*

How much exercise in W patient could perform ?

Can subject achieve normal VO_2 ($\geq 85\%$) or not ?

Is there a cardiovascular limitation?

- Is there a premature metabolic acidosis - Low AT
- Low O₂ pulse at termination of exercise
- Large HR reserve
- Long HRR time

Is there a ventilatory (mechanics) limitation?

- Low BR $\leq 15\%$
- DHI with EFL

Does pulmonary gas exchange contribute to exercise limitation?

- Fall in Oxygen saturation $\geq 4\%$

Is it poor conditioning / muscular limitation ?

Contraindications to CPET

Acute MI

Unstable angina

Unstable arrhythmia

Acute endocarditis,
myocarditis,
pericarditis

Syncope

Severe, symptomatic
AS

Uncontrolled CHF

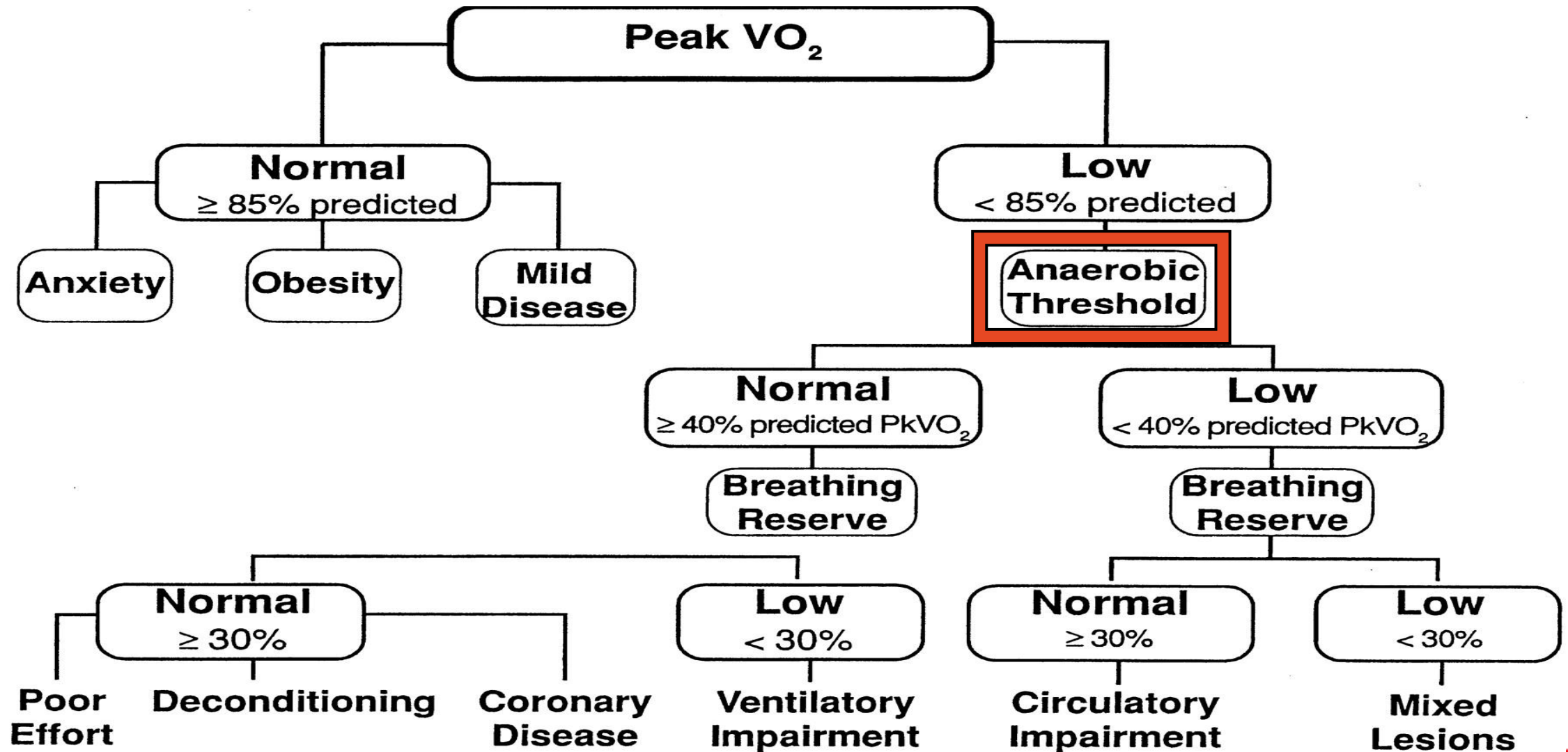
Acute PE, DVT

Respiratory failure

SpO₂ <88% on RA

Acute significant non-
cardiopulmonary
disorder that may
affect or be adversely
affected by exercise

Algorithm to Interpret CPET Report



Reduced Vo₂ peak : Patterns for Causes

CPET Variable	COPD	ILD	PVD	Obesity	Heart Failure	Deconditioning
LT / AT	Indeterminate/ Low / normal	Normal / Low	Reduced	Reduced / normal	Reduced	Reduced
VE Reserve	Reduced or Zero	Reduced or normal	Normal	Normal	Normal	Normal
HRR	Normal / increased	Normal / increased	Normal	Normal	Reduced / Normal	Normal
O ₂ Pulse	Reduced	Reduced	Reduced	Normal	Reduced	Reduced
Oxygen saturation (sPo2)	+ /-	++	++	Nil	Nil	Nil
End Tidal CO2 Late in Exercise	Increase or Stable	Decrease	Decrease	Decrease	Decrease	Increase or Stable
Stopping Test	Dyspnea	Dyspnea	Leg Fatigue	Fatigue	Leg Fatigue	Dyspnea, Fatigue,

	Disease Category				
Variable	Normal Patient	Cardiovascular Disease	Obstructive Lung Disease	Pulmonary Vascular Disease /ILD #	Neuromuscular Disease
VO _{2,max}	Normal *	Decreased	Decreased	Decreased	Decreased
Heart Rate Reserve	Absent to small reserve (< 20 bpm)	Absent to small reserve (< 20 bpm)	Large (> 30 bpm)	Small (< 20-30 bpm)	Large (> 30 bpm)
V _{E,max} /MVV (Ventilatory Reserve)	< 0.8	< 0.8	> 0.8	< 0.8	< 0.8
Ventilatory Threshold	Present	Present	Absent	Present	Usually present
Dead Space (V _D /V _T)	Decreases	Decreases	Decreases	Remains stable or increases	Decreases
Oxygen Saturation	Stable	Stable	Decreases	Decreases	Stable
End-Tidal CO ₂ (in late exercise)	Decrease	Decrease	Increase or stable	Decrease	Increase or stable
Reason for Stopping	Leg Fatigue	Leg Fatigue	Dyspnea	Dyspnea, leg fatigue	Fatigue

Note:

* “Normal” or “decreased” refers to how the variable changes relative to age, gender and size matched individuals.

Interstitial lung disease patients demonstrate a pattern very similar to the pulmonary vascular pattern and can only be differentiated based on their PFTs and chest imaging.



 Athol U Wells



 Shirmila Withana



 Dave Singh



 Colm McCabe



 P Haldar

Arriving : Octane PACS -25

15, 16 & 17 August 2025



 Omar Usmani



 Konstantina Kontogianni



 F. Anthony De Soyza

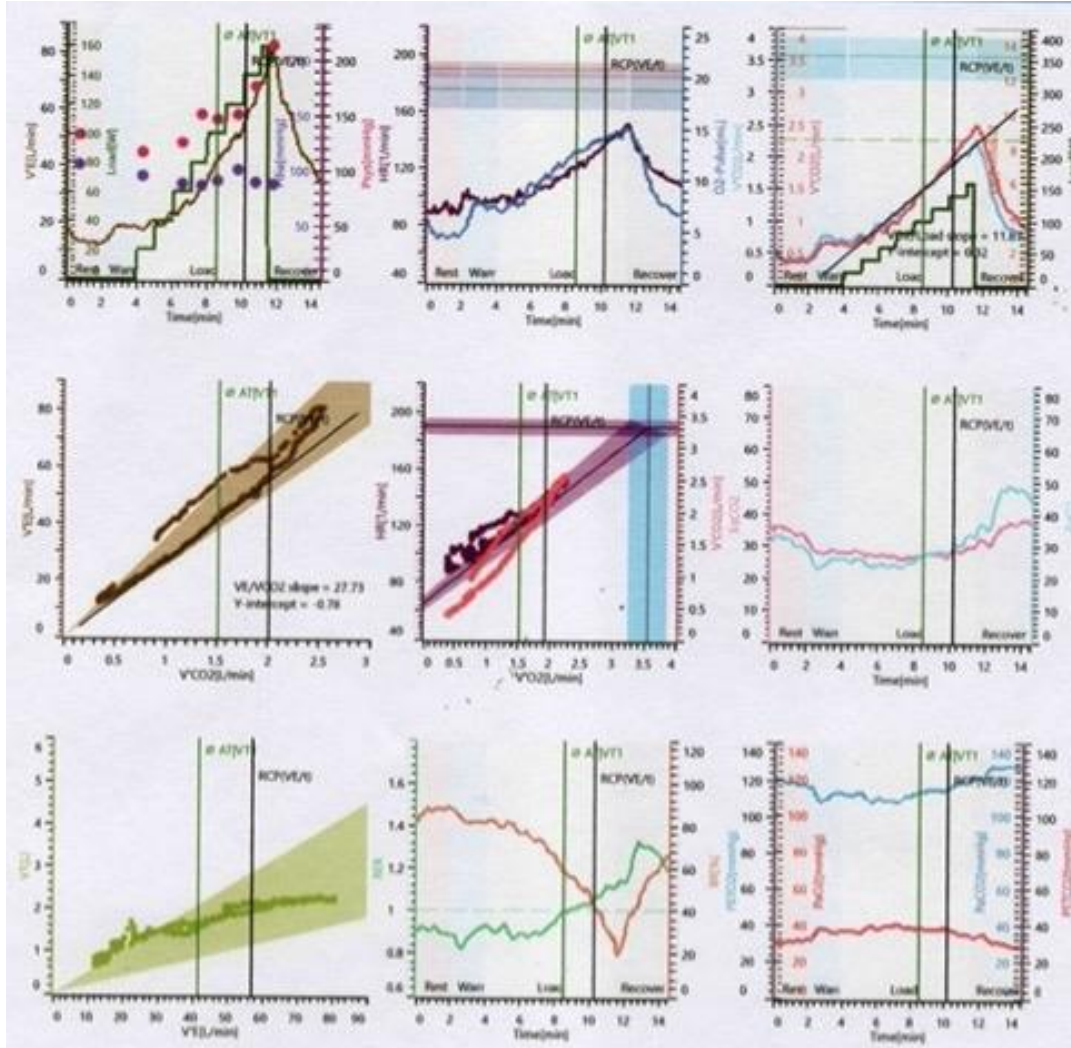


 Marlies Weisenbeek



 Rakesh Panchal

Case : 30 Years, Male with SOB



No desaturation on CPET

Exercise Details:		Pred	Rest	Warm up	AT	% Pred	RCP	Max. Load	% Pred	Recovery
Time	[min]	-	01:54	03:57	08:31	-	10:12	11:22	-	14:28
Load	[W]	227	0	0	100	44 %	140	160	70 %	0

Metabolic Response:

V'O2	[L/min]	3.56	0.40	0.71	1.52	43 %	1.92	2.21	62 %	0.76
V'O2/kg	[mL/min/kg]	39.56	4.50	7.86	16.94	43 %	21.36	24.54	62 %	8.47
V'CO2	[L/min]	3.92	0.36	0.66	1.52	39 %	2.02	2.46	63 %	0.91
METS	[]	-	1.3	2.2	4.8	-	6.1	7.0	-	2.4
RER	[]	-	0.88	0.93	1.00	-	1.05	1.11	-	1.19
REE	[kcal/day]	-	2837	5033	11040	-	14102	16418	-	5747

Ventilatory Response:

V'E	[L/min]	100.50	11.92	18.48	41.77	42 %	56.87	74.11	74 %	33.96
VT	[L]	0.64	0.67	1.10	1.65	257 %	2.13	2.24	348 %	1.43
BF	[1/min]	20	21	18	27	135 %	29	35	175 %	26
BR	[%]	28.0	88.1	81.6	58.4	209 %	43.4	26.2	94 %	66.2
Vd%VT	[%]	-	5.87	10.57	15.14	-	18.24	17.39	-	15.78

Cardiovascular Response:

HR	[1/min]	190	94	96	120	63 %	138	152	80 %	109
O2-Pulse	[mL]	18.7	4.5	7.3	12.8	68 %	14.3	15.0	80 %	6.8
HRR	[1/min]	-	96	94	70	-	52	38	-	81
V'CO2	[L/min]	3.92	0.36	0.66	1.52	39 %	2.02	2.46	63 %	0.91

Gas Exchange:

EqO2	[]	-	29.5	26.1	27.4	-	29.6	33.6	-	44.6
EqCO2	[]	-	33.4	28.1	27.5	-	28.1	30.2	-	37.3
PETCO2	[mmHg]	-	32	37	38	-	38	35	-	29
PETO2	[mmHg]	-	117	113	114	-	116	120	-	127

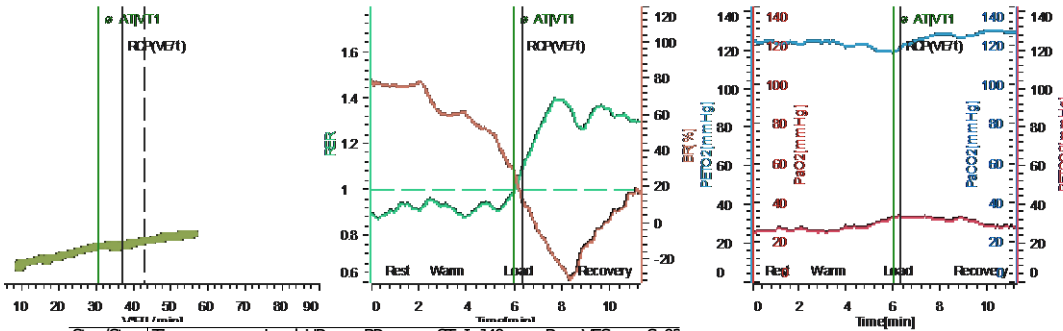
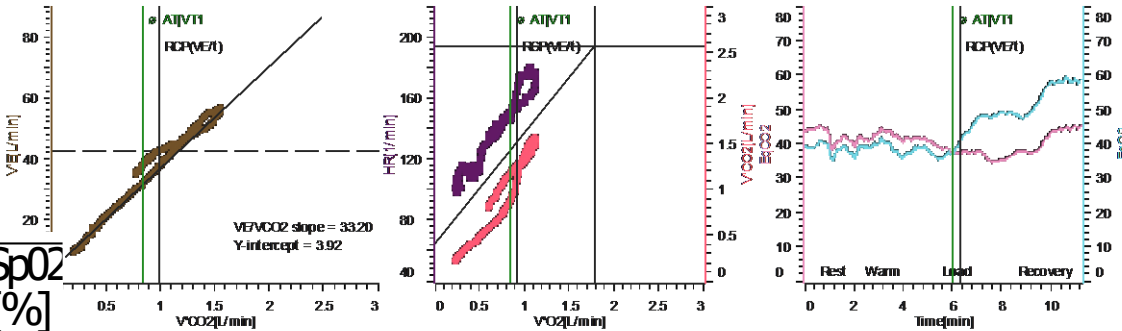
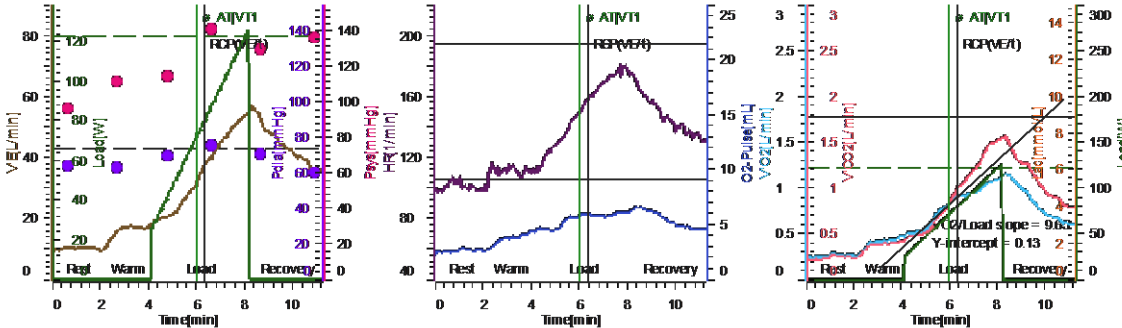
Case

Exercise Details:		Pred	Rest	Warm up	AT	% Pred	RCP	Max. Load	% Pred	Recovery
Time	[min]	-	02:06	04:04	05:59	-	06:19	08:09	-	11:12
Load	[W]	123	0	0	71	58 %	79	125	102 %	0

Metabolic Response:										
V'O2	[L/min]	1.78	0.26	0.49	0.83	47 %	0.92	1.12	63 %	0.61
V'O2/kg	[mL/min/kg]	32.98	4.91	9.00	15.46	47 %	16.96	20.82	63 %	11.33
V'CO2	[L/min]	1.96	0.24	0.43	0.83	42 %	0.99	1.54	79 %	0.79
METS	[]	-	1.4	2.6	4.4	-	4.8	5.9	-	3.2
RER	[]	-	0.91	0.89	0.99	-	1.08	1.38	-	1.30
REE	[kcal/day]	-	1863	3418	6026	-	6748	8814	-	4706

Ventilatory Response:

Step/Stage	Time [mm:ss]	Load [W]	HR [/min]	BP [mmHg]	ST I J40 [mm]/[mV/s]	Borg VES [] [count]	SpO2 [%]
Sitting	02:08	0	98	97 / 64	0.2 / 0.0	-- 0	97
Warm-up	04:08	0	114	112 / 63	1.1 / 0.8	-- 0	96
STmax	04:10	26	110	-- / --	0.8 / 0.5	-- --	--
Step 1	01:00 (05:08)	50	129	115 / 70	0.5 / 0.2	-- 0	96
Step 2	02:00 (06:08)	75	152	126 / 74	0.2 / 0.0	-- 1	96
Step 3	03:00 (07:08)	99	170	135 / 76	0.0 / 0.3	-- 3	95
Step 4	04:00 (08:08)	124	174	146 / 72	-0.0 / 0.3	-- 0	94
Max Load	04:03 (08:11)	126	175	150 / 75	0.0 / 0.4	-- 0	93
Recovery	01:00 (09:11)	0	155	136 / 71	0.2 / 0.6	-- 0	94
Recovery	02:00 (10:11)	0	140	132 / 72	0.2 / 0.7	-- 1	96
Recovery	03:00 (11:11)	0	130	118 / 68	0.0 / 0.6	-- 0	97
EoE	03:02 (11:13)	0	132	-- / --	0.0 / 0.6	-- 0	96



Step/Stage	Time [mm:ss]	Load [W]	HR [/min]	BP [mmHg]	ST I J40 [mm]/[mV/s]	Borg VES [] [count]	SpO2 [%]
Sitting	02:08	0	98	97 / 64	0.2 / 0.0	-- 0	97
Warm-up	04:08	0	114	112 / 63	1.1 / 0.8	-- 0	96
STmax	04:10	26	110	-- / --	0.8 / 0.5	-- --	--
Step 1	01:00 (05:08)	50	129	115 / 70	0.5 / 0.2	-- 0	96
Step 2	02:00 (06:08)	75	152	126 / 74	0.2 / 0.0	-- 1	96
Step 3	03:00 (07:08)	99	170	135 / 76	0.0 / 0.3	-- 3	95
Step 4	04:00 (08:08)	124	174	146 / 72	-0.0 / 0.3	-- 0	94
Max Load	04:03 (08:11)	126	175	150 / 75	0.0 / 0.4	-- 0	93
Recovery	01:00 (09:11)	0	155	136 / 71	0.2 / 0.6	-- 0	94
Recovery	02:00 (10:11)	0	140	132 / 72	0.2 / 0.7	-- 1	96
Recovery	03:00 (11:11)	0	130	118 / 68	0.0 / 0.6	-- 0	97
EoE	03:02 (11:13)	0	132	-- / --	0.0 / 0.6	-- 0	96

Case

Exercise Details:

		Pred	Rest	Warm up	AT	% Pred	RCP	Max. Load	% Pred	Recovery
Time	[min]	-	01:54	03:54	08:11	-	09:17	09:23	-	14:29
Load	[W]	145	0	0	78	54 %	94	96	66 %	0

Metabolic Response:

V'O2	[L/min]	1.96	0.31	0.58	1.25	64 %	1.38	1.37	70 %	0.48
V'O2/kg	[mL/min/kg]	28.77	4.57	8.55	18.41	64 %	20.32	20.16	70 %	7.13
V'CO2	[L/min]	2.15	0.32	0.55	1.26	58 %	1.46	1.46	68 %	0.48
METS	[]	-	1.3	2.4	5.3	-	5.8	5.8	-	2.0
RER	[]	-	1.02	0.95	1.00	-	1.06	1.06	-	0.98
REE	[kcal/day]	-	2240	4150	9079	-	10141	10073	-	3483

Ventilatory Response:

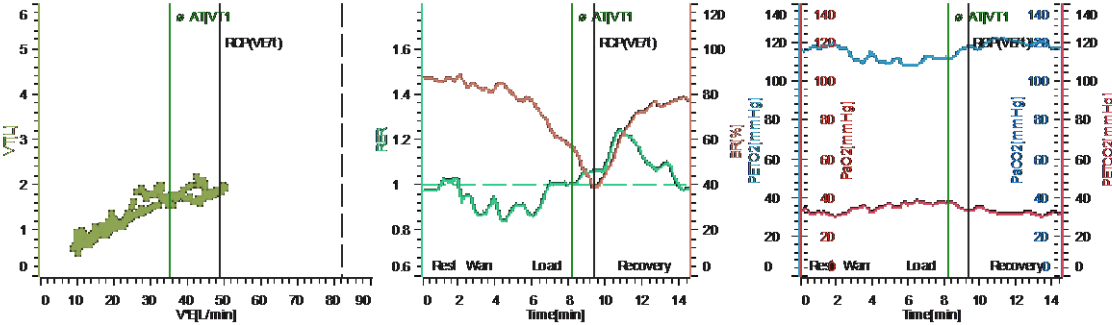
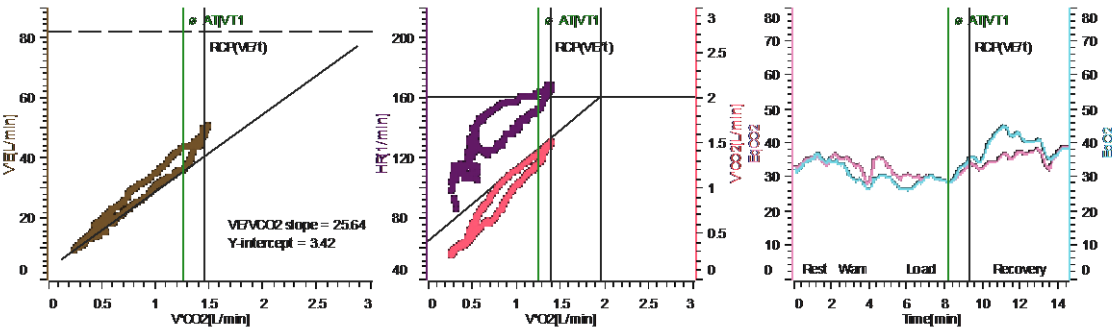
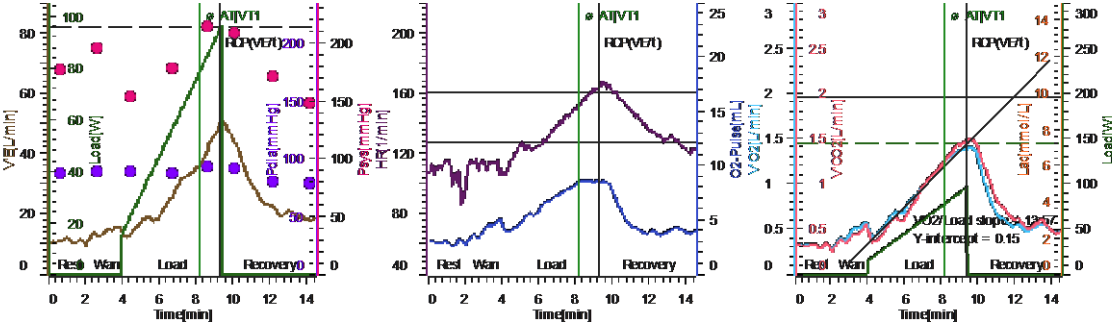
V'E	[L/min]	81.90	10.93	15.45	35.38	43 %	48.72	49.62	61 %	18.48
VT	[L]	0.48	0.89	0.95	1.54	318 %	1.84	1.90	392 %	0.91
BF	[1/min]	20	17	22	25	126 %	30	29	145 %	22
BR	[%]	28.0	86.6	81.1	56.8	203 %	40.5	39.4	141 %	77.4
Vd%VT	[%]	-	6.16	1.54	15.97	-	21.37	23.07	-	21.44

Cardiovascular Response:

HR	[1/min]	161	93	105	152	94 %	163	166	103 %	123
O2-Pulse	[mL]	12.2	3.0	5.1	8.4	69 %	8.5	8.4	69 %	4.0
HRR	[1/min]	-	68	56	9	-	-2	-5	-	38
V'CO2	[L/min]	2.15	0.32	0.55	1.26	58 %	1.46	1.46	68 %	0.48

Gas Exchange:

EqO2	[]	-	35.2	26.6	28.3	-	35.2	36.2	-	38.1
EqCO2	[]	-	34.3	28.0	28.1	-	33.4	34.0	-	38.7
PETCO2	[mmHg]	-	30	32	37	-	33	33	-	32
PETO2	[mmHg]	-	119	115	112	-	117	117	-	117



Step/Stage	Time [mm:ss]	Load [W]	HR [1/min]	BP [mmHg]	ST I J40 [mm]/[mV/s]	Borg VES [count]	SpO2 [%]
Sitting	02:01	0	93	148 / 84	-0.1 / 0.7	-	99
Warm-up	04:01	0	110	157 / 86	0.2 / 1.2	1	99
Step 1	01:00 (05:01)	30	123	169 / 89	-0.0 / 0.8	1	98
Step 2	02:00 (06:01)	45	124	175 / 88	0.0 / 0.7	2	99
Step 3	03:00 (07:01)	60	138	179 / 92	0.0 / 0.7	2	98
Step 4	04:00 (08:01)	75	149	188 / 91	-0.0 / 0.8	3	99
STmax	08:40	85	157	- / -	-0.3 / 0.8	-	-
Step 5	05:00 (09:01)	90	163	199 / 93	-0.2 / 1.1	4	99
Max Load	05:25 (09:26)	96	166	218 / 98	-0.2 / 1.2	6	98
Recovery	01:00 (10:26)	0	157	209 / 91	0.0 / 1.7	2	98
Recovery	02:00 (11:26)	0	145	185 / 86	0.2 / 1.5	1	98
Recovery	03:00 (12:26)	0	133	171 / 84	0.2 / 1.2	1	98
Recovery	04:00 (13:26)	0	129	158 / 82	0.1 / 0.9	-	98
Recovery	05:00 (14:26)	0	123	148 / 81	0.1 / 1.0	-	98
EoE	05:04 (14:30)	0	123	- / -	0.1 / 1.0	-	98

No desaturation on CPET

Case

Exercise Details:

Time	[min]	-	00:58	02:57	05:30	-	07:27	07:59	-	11:36
Load	[W]	223	0	0	87	39 %	135	149	67 %	0

Metabolic Response:

V'O2	[L/min]	3.84	0.28	0.53	1.00	26 %	1.40	1.52	40 %	0.53
V'O2/kg	[mL/min/kg]	36.58	2.67	5.07	9.57	26 %	13.35	14.46	40 %	5.07
V'CO2	[L/min]	4.22	0.24	0.47	0.98	23 %	1.60	1.74	41 %	0.68
METS	[]	-	0.8	1.4	2.7	-	3.8	4.1	-	1.4
RER	[]	-	0.86	0.88	0.97	-	1.14	1.14	-	1.28
REE	[kcal/day]	-	1950	3740	7231	-	10476	11353	-	4084

Ventilatory Response:

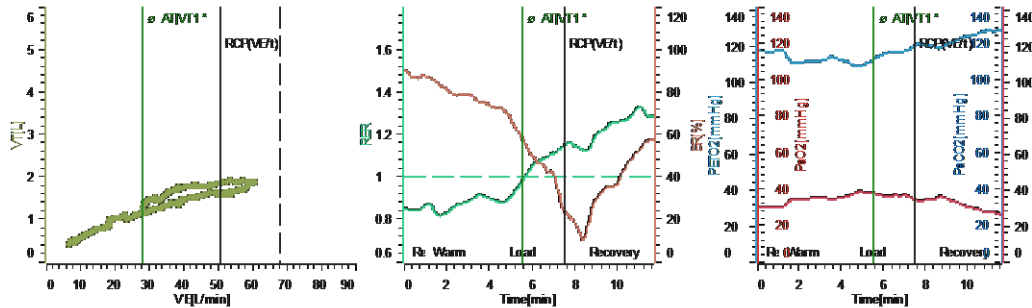
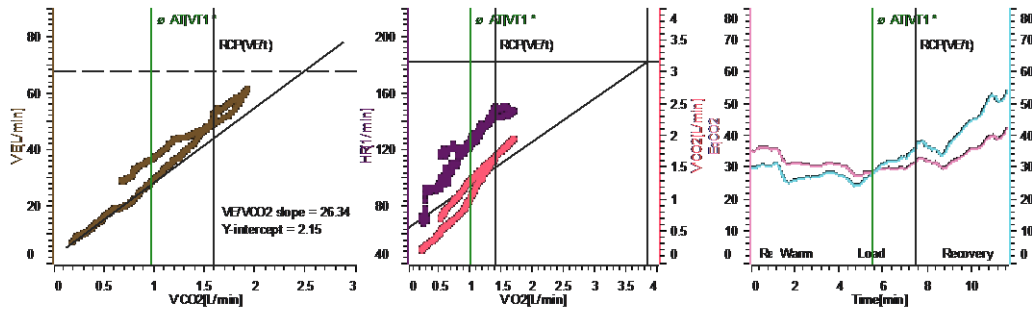
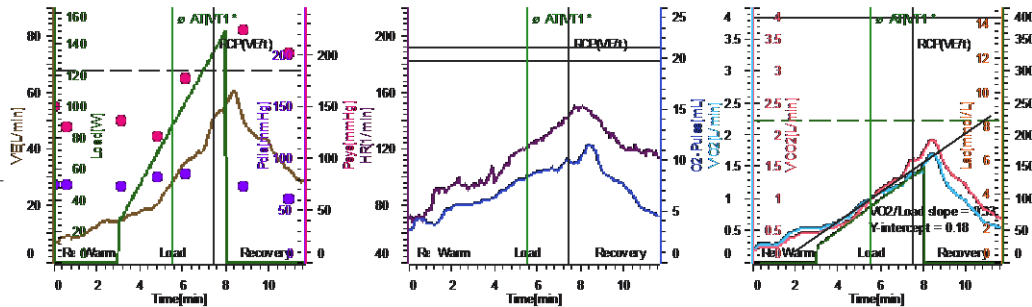
V'E	[L/min]	67.80	8.62	14.28	28.06	41 %	50.51	55.40	82 %	28.80
VT	[L]	0.75	0.44	0.71	1.11	148 %	1.58	1.64	219 %	1.32
BF	[1/min]	20	24	24	28	142 %	35	37	186 %	25
BR	[%]	28.0	87.3	78.9	58.6	209 %	25.5	18.3	65 %	57.5
Vd%VT	[%]	-	-	8.59	15.15	-	19.37	19.11	-	17.89

Cardiovascular Response:

HR	[1/min]	182	77	92	121	66 %	142	148	81 %	114
O2-Pulse	[mL]	21.1	3.8	5.7	8.4	40 %	10.0	10.3	49 %	4.5
HRR	[1/min]	-	105	90	61	-	40	34	-	68
V'CO2	[L/min]	4.22	0.24	0.47	0.98	23 %	1.60	1.74	41 %	0.68

Gas Exchange:

EqO2	[]	-	30.7	26.8	27.9	-	36.0	36.5	-	54.1
EqCO2	[]	-	35.6	30.4	28.7	-	31.6	31.9	-	42.1
PETCO2	[mmHg]	-	30	36	38	-	35	34	-	26
PETO2	[mmHg]	-	118	112	112	-	120	120	-	129



Step/Stage	Time [mm:ss]	Load [W]	HR [1/min]	BP [mmHg]	ST I J40 [mm]/[mV/s]	Borg VES [count]	SpO2 [%]
Sitting	01:02	0	77	131 / 70	0.5 / 0.3	— 0	96
Warm-up	03:02	0	95	132 / 72	0.2 / 0.2	— 0	97
STmax	03:10	29	96	— / —	0.3 / 0.0	— —	—
Step 1	00:59 (04:01)	50	96	137 / 73	0.3 / 0.1	— 0	97
Step 2	01:59 (05:01)	75	117	142 / 80	0.2 / 0.1	— 0	97
Step 3	02:59 (06:01)	99	126	148 / 84	0.3 / 0.3	— 1	98
Step 4	03:59 (07:01)	124	138	160 / 86	0.1 / 0.5	— 2	96
Max Load	04:59 (08:01)	149	148	177 / 86	0.1 / 0.7	— 0	97
Recovery	01:00 (09:01)	0	138	190 / 88	0.2 / 0.6	— 0	96
Recovery	02:00 (10:01)	0	121	220 / 90	0.2 / 0.3	— 0	97
Recovery	03:00 (11:01)	0	118	202 / 88	0.1 / 0.3	— 0	96
EoE	03:37 (11:38)	0	114	192 / 84	0.0 / 0.4	— 0	96

Case

Exercise Details:

		Pred	Rest	Warm up	AT	% Pred	RCP	Max. Load	% Pred	Recovery
Time	[min]	-	02:10	04:11	05:47	-	08:31	09:34	-	12:43
Load	[W]	129	0	0	20	16 %	50	60	47 %	0

Metabolic Response:

V'O2	[L/min]	1.88	0.30	0.55	0.60	32 %	0.68	0.66	35 %	0.61
V'O2/kg	[mL/min/kg]	25.14	4.06	7.33	8.06	32 %	9.02	8.81	35 %	8.16
V'CO2	[L/min]	2.07	0.24	0.49	0.56	27 %	0.78	0.78	38 %	0.61
METS	[]	-	1.2	2.1	2.3	-	2.6	2.5	-	2.3
RER	[]	-	0.79	0.90	0.93	-	1.16	1.18	-	1.00
REE	[kcal/day]	-	2085	3876	4295	-	5061	4968	-	4419

Ventilatory Response:

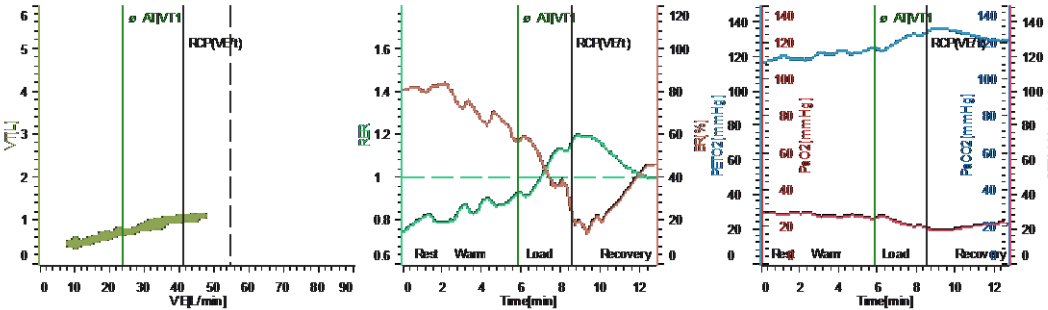
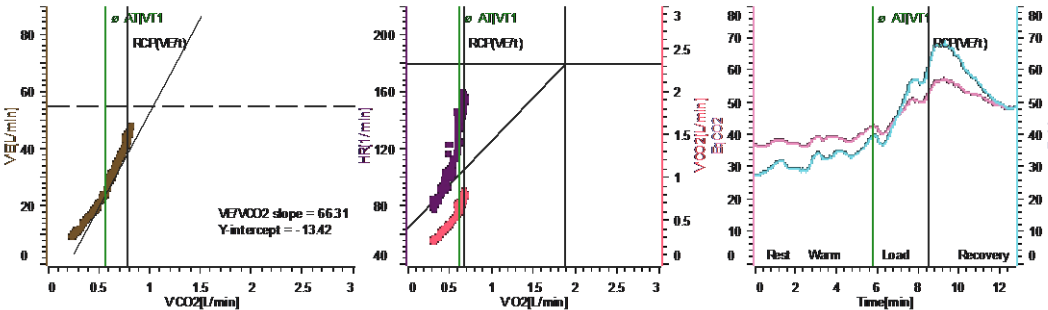
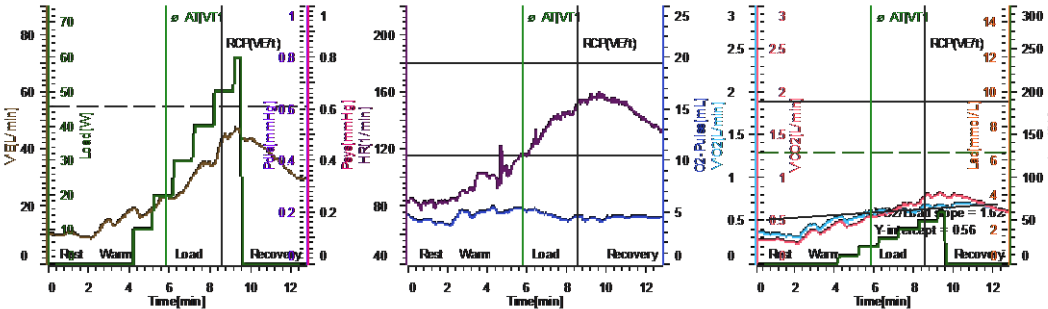
V'E	[L/min]	54.90	8.94	19.06	24.07	44 %	41.36	44.06	80 %	29.67
VT	[L]	0.54	0.45	0.65	0.67	124 %	1.00	1.05	196 %	0.79
BF	[1/min]	20	25	35	39	197 %	44	45	225 %	40
BR	[%]	28.0	83.7	65.3	56.2	201 %	24.7	19.7	71 %	46.0
Vd%VT	[%]	-	2.84	5.80	12.18	-	15.65	15.65	-	15.55

Cardiovascular Response:

HR	[1/min]	180	84	101	117	65 %	150	159	88 %	132
O2-Pulse	[mL]	10.5	3.6	5.4	5.3	51 %	4.6	4.2	40 %	4.5
HRR	[1/min]	-	96	79	63	-	30	21	-	48
V'CO2	[L/min]	2.07	0.24	0.49	0.56	27 %	0.78	0.78	38 %	0.61

Gas Exchange:

EqO2	[]	-	29.3	34.7	39.8	-	61.1	66.7	-	48.5
EqCO2	[]	-	37.0	38.6	42.9	-	52.8	56.3	-	48.6
PETCO2	[mmHg]	-	29	27	26	-	21	19	-	23
PETO2	[mmHg]	-	118	123	125	-	134	136	-	129



Step/Stage	Time	Load	HR	BP	ST 1 J40	Borg VES	SpO2
	[mm:ss]	[W]	[/min]	[mmHg]	[mm]/[mL/s]	[] [count]	[%]
Sitting	02:14	0	85	100 / 60	0.5 / 0.3	-- 0	92
Warm-up	04:14	0	101	104 / 60	1.3 / 2.4	-- 0	89
STmax	04:20	10	102	-- / --	0.8 / 1.6	-- --	--
Step 1	01:00 (05:14)	10	106	108 / 62	0.7 / 1.4	-- 0	88
Step 2	02:00 (06:14)	20	120	110 / 64	0.7 / 1.4	-- 0	88
Step 3	03:00 (07:14)	30	140	116 / 63	0.6 / 1.1	-- 0	86
Step 4	04:00 (08:14)	40	144	122 / 68	0.4 / 1.2	-- 0	86
Step 5	05:00 (09:14)	50	158	128 / 71	0.3 / 1.2	-- 2	85
Max Load	05:21 (09:35)	60	159	138 / 74	0.4 / 1.1	-- 1	86
Recovery	01:00 (10:35)	0	152	120 / 70	0.4 / 1.2	-- 0	88
Recovery	02:00 (11:35)	0	144	116 / 68	0.4 / 0.8	-- 1	89
Recovery	03:00 (12:35)	0	136	108 / 62	0.3 / 0.9	-- 0	90
EoE	03:09 (12:44)	0	132	-- / --	0.4 / 1.1	-- 0	--