CPETs- A Practical Approach

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Objectives

1

Identify key components of a cardiopulmonary exercise test.

2

List important parameters measured during CPET and describe what patient actions influence those parameters.

3

Review strategies of selecting anaerobic threshold.

What is cardiopulmonary exercise testing?

Used by cardiologists	Used by pulmonologists

• Evaluates possible ischemic changes as work increases
• Changes in ECG and blood pressure are monitored
	• In addition to monitoring ECG and blood pressure, CPET monitors exhaled gases
	  • O2
	  • CO2
	  • Ve
	  • SpO2
	  • ABGs

Are exercise tests the same in the PFT lab?

NO!

This talk is about CPETs (CardioPulmonary Exercise Testing)

Before and After Exercise Spirometry is a challenge test

- Obtain baseline spirometry
- Expose patient to exercise (bike at 85% of max HR) for a duration of time
- Repeat serial spirometry efforts after stopping
- Evaluate FEV1 and compare to baseline
- Pt must withhold inhaled respiratory meds prior to challenge testing

Indications For CPET

- Evaluation of exertional dyspnea
- Development of an exercise program
- Direct measurement of peak O2 consumption per unit time
- Risk stratification and prognosis in heart failure
- Optimization of rate-adaptive or biventricular pacemaker
- Congenital heart disease-surgical candidate/response to treatment
- Disability determination
- Assess functional significance of regurgitant valvular heart disease
- Assess results of medical/surgical therapy

Parameters	Units
Rest	
SpO_2	[%]
HR	[bpm]
BP sys	mmHg
BP dia	mmHg
VT	[l]
RR	[1/min]
$V'O_2$	[l/min]
$V'O_2/kg$	[ml/min/kg]
$V'O_2/HR$	[ml]
$V'E/V'CO_2$	
SV	[ml]
cLa	[mmol/l]
pH	
BE	
Hb	[g/dl]
VO_2 peak	
SpO_2	[%]
HR	[bpm]
VT	[l]
RR	[1/min]
P	[W]
P/kg	[W/kg]
$V'O_2$	[l/min]
$V'O_2/kg$	[ml/min/kg]
$V'O_2/HR$	[ml]
$V'E/V'CO_2$	
Qc	[l/min]
SV	[ml]
$(a-v)DO_2$	[ml/100 ml]
cLa	[mmol/l]
BORG	
pH	
BE	

Ventilation Parameters

- Ve (minute ventilation) = Vt x RR.
  - Normally 5-10 lpm at rest; up to 100-200 lpm with exercise
- BR (breathing reserve or ventilatory reserve)

O_2 Consumption Parameters

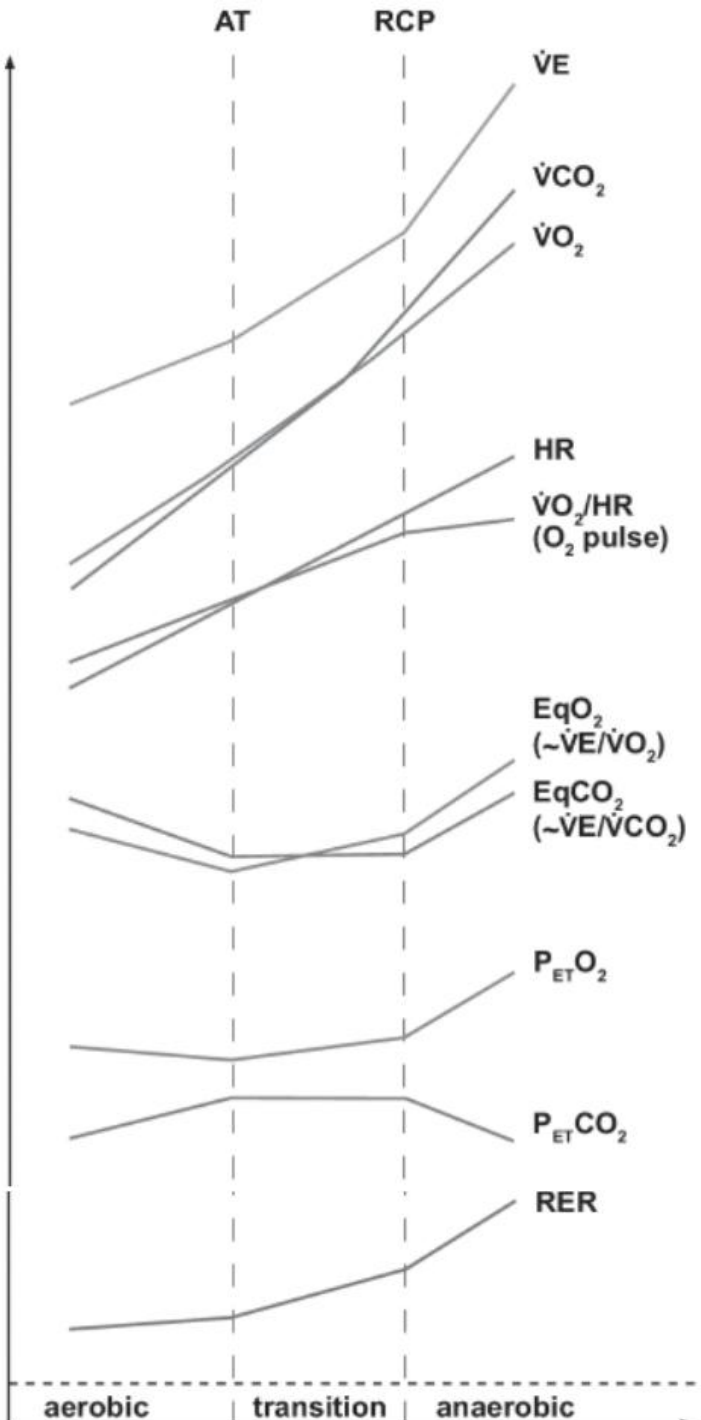
- VO_2 (oxygen consumption or oxygen uptake) = **BEST INDICATOR OF WORKLOAD PERFORMED.**
  - Wide range: 15-80 mL O_2/kg/min (healthy elderly to elite athlete)
- Peak VO_2 (highest VO_2 achieved during or near peak exercise, $VO_{2}max$)
- VCO_2 (CO_2 production or CO_2 output).
  - Normally 0.2 lpm at rest; up to 4 lpm with exercise
- RER (respiratory exchange ratio)= VCO_2/VO_2 = the relationship between VO_2 and VCO_2 *at the mouth* which represents gas exchange *in the lung.*
  - Normally 0.85 at rest,
  - Increases to 1.0+ at **AT** (anaerobic, ventilatory or lactate threshold).

Cardiac Parameters

- HR
- O2 pulse = VO2/HR
  - Increased if HR is low; decreased if HR is high (cardiac disease)
  - Normally 2.5-4 at rest and 10-15 with exercise

Ventilation/Perfusion Parameters

- PETCO2 (partial pressure of CO2 at FRC)
  - Reflects V/Q matching in the lung and the level of PaCO2.
- Ve/VCO2 (ventilatory equivalent for CO2 or ventilation-CO2 production ratio)
  - Reflects matching of V to Q
  - Normally 25-35 at rest
- Ve/VO2 (ventilatory equivalent for O2)
  - Normally 20-30 at rest


AT
RCP
V̇E
V̇CO2
V̇O2
HR
V̇O2/HR
(O2 pulse)
EqO2
(~V̇E/V̇O2)
EqCO2
(~V̇E/V̇CO2)
PETO2
PETCO2
RER
aerobic
transition
anaerobic

VO2 Max

- It’s the maximum volume of O2 the body can process.
- It’s a measure of the capacity the body needs to use O2 when exercising.
- VO2 max is key to understanding and improving fitness
  - Having a baseline leads to training to improve future VO2 max results
  - Training at or near your VO2 max improves the body’s ability to process a greater volume of O2
    - 20m interval workout: 3 min at VO2 max pace
    - 2m easy pace
    - Repeat 4 times

VO2

Lung Capacity and Heart Volume

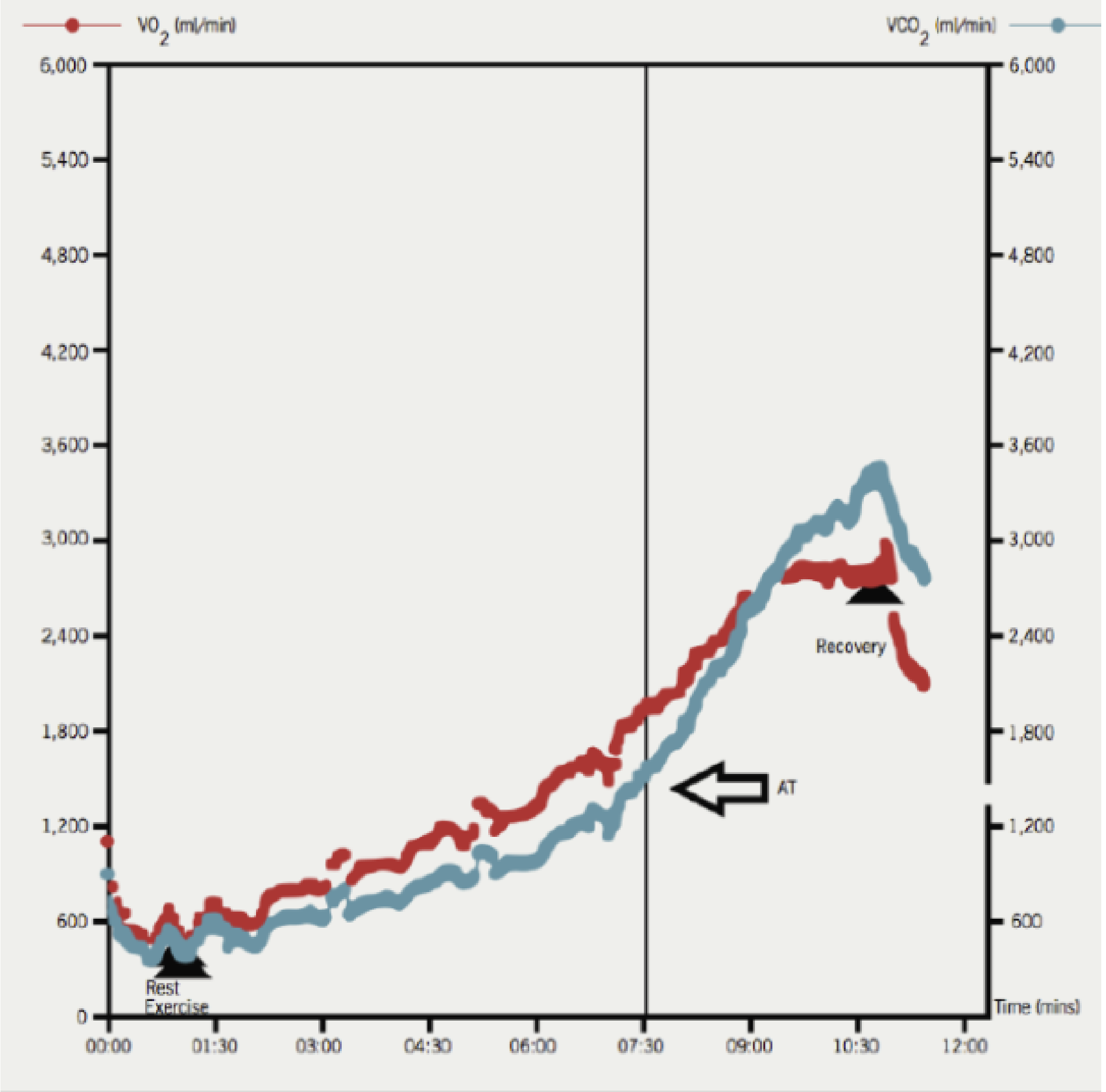
The more O2 the lungs can intake and the more oxygenated blood the heart can pump, the higher the VO2

Capillary Delivery

The more oxygenated blood the circulation can transport to the muscles, the higher the VO2

Muscle Efficiency

The more the muscles can extract and use O2, the higher the VO2



Key: AT = anaerobic threshold; VCO_2 = rate of elimination of carbon dioxide; VO_2 = oxygen uptake

VO2 Max Values by Age and Gender

Age Group	5th Percentile	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	95th Percentile
Men							
20-29	29.0	32.1	40.1	48.0	55.2	61.8	66.3
30-39	27.2	30.2	35.9	42.4	49.2	56.5	59.8
40-49	24.2	26.8	31.9	37.8	45.0	52.1	55.6
50-59	20.9	22.8	27.1	32.6	39.7	45.6	50.7
60-69	17.4	19.8	23.7	28.2	34.5	40.3	43.0
70-79	16.3	17.1	20.4	24.4	30.4	36.6	39.7
Women							
20-29	21.7	23.9	30.5	37.6	44.7	51.3	56.0
30-39	19.0	20.9	25.3	30.2	36.1	41.4	45.8
40-49	17.0	18.8	22.1	26.7	32.4	38.4	41.7
50-59	16.0	17.3	19.9	23.4	27.6	32.0	35.9
60-69	13.4	14.6	17.2	20.0	23.8	27.0	29.4
70-79	13.1	13.6	15.6	18.3	20.8	23.1	24.1

What happens during a CPET?

The patient performs spirometry and MVV maneuvers

- Pt should be actively doing MVV maneuver when measuring begins
- Goal is a RR of 90-120
- Allow pt to rest and repeat MVV (repeatable within 10%)
- If MVV is 10% < than FEV1, then repeat MVV post CPET
  - Possible issues with neuromuscular disease

Watts (work rate) is selected for the patient

- Watts = power output (where power is work/time)
  - Evaluate MVV
  - Evaluate FEV1 x 40
  - Consider the patient's regular physical activity/workout habits
  - Evaluate the lower extremities
- Goal is for the patient to exercise 8-12 minutes
- How many floors can you walk up quickly without stopping?
  - One floor- about 50W (5W/min for a 10min test)-easy hiking or golf
  - Two floors-about 100W (10W/min)-"Nordic walking", cycling, gardening
  - Three floors-125-150W (15W/min)- swimming, mountain hiking, etc.
  - Four floors-200W (20W/min)- compare to running at $\geq$ 6.2 mph

- Med list and recent meals are reviewed with the patient
  - Use of B-blockers
    - Results in lower HR during exercise
    - Prognosis of interpretation may be limited in patients where peak VO2 is less than 14 mL/kg/min

  - Understand impact of food on the pulmonary patient
    - Severe dyspnea = a conscious effort to breathe
    - Extra effort can increase the REE (resting energy expenditure) up to 15%
    - COPD pts can use 10 x as many calories breathing as a healthy person does
      - Severe COPD causes progressive weight loss
        - More calories are burned, rate of infections increase, vicious cycle of decreased food intake and increased fatigue
        - Low BMI → poor prognosis

  - Conversion of carbs, fats and proteins to energy and CO_2 in the cells
    - Carbs: produce the most CO_2 RQ = 1
    - Fats: produce the least CO_2 RQ = 0.7
    - Proteins: RQ = 0.8

Nutrients

Carbs

- Calories form sugars and starches that fuel muscle and brain cells
- O2 combines w/glucose to release ATP (adenosine triphosphate) → used during exercise

Fats

- Stored energy burned during all activity levels (sleeping to long training runs)
- Necessary for brain and nerve tissue; protects organs; helps vitamin absorption

Protein

- Essential for building/repairing muscles and hormone synthesis
- Digested into amino acids and rebuilds muscles

CPET measurements begin (resting phase)

- Patient is fitted with mask and seal is confirmed
- Hemodynamic status is obtained at baseline
- Represents actual cardiopulmonary and metabolic baseline
- ECG is printed and approved by physician
- ABG is drawn
- Obtain BORG readings

Exercise begins (unloaded phase)

- Patient starts pedaling at a rate of 65-70 RPMs (minimum of 60 RPMs)
- SpO2, BP and BORG is recorded every minute
- Warmup phase is 2 minutes at zero Watts, then work automatically starts

Testing Phase (incremental exercise)

- Work increases incrementally every minute
  - If the Watts are set at 10, then it will increase by 10 every minute
- Monitor patient closely for end of test clues
  - Unable to provide BORG assessment
  - Changes in pedaling cadence/unable to maintain RPMs
  - Increasing HR and/or BP
  - Crossing of the VO_2/VCO_2- once it crosses, they need to keep going
- When is the exercise finished?
  - Max HR was obtained
  - Max ventilation was obtained
  - RER > 1.1
  - Obvious exhaustion


201
96
20.5
97

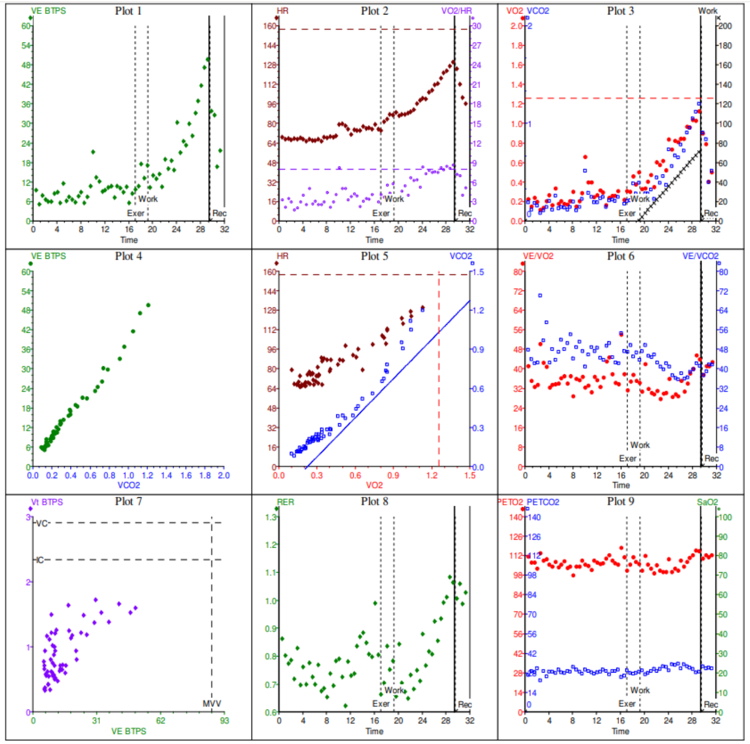
Recovery Phase

- Patient continues to pedal at a lower cadence (40 rpms or less) for 3-5 minutes
- Patient must cool down by slowing their work, **do not allow them to stop pedaling**
  - The pulse is still high and body temp is increased
  - Patient may pass out or feel sick if they stop immediately
  - Cool down allows for a gradual recovery of HR and blood pressure.
- Obtain ABG as soon as possible into the recovery phase (within 2 minutes)
  - This captures the ABG results close to VO2max
  - Usual findings with exercise (compared to baseline ABGs)
    - pH decreases
    - PaCO2 decreases
    - HCO3 decreases
    - Lactate increases
    - Hb increases

Evaluating Wasserman's 9-Panel Graph

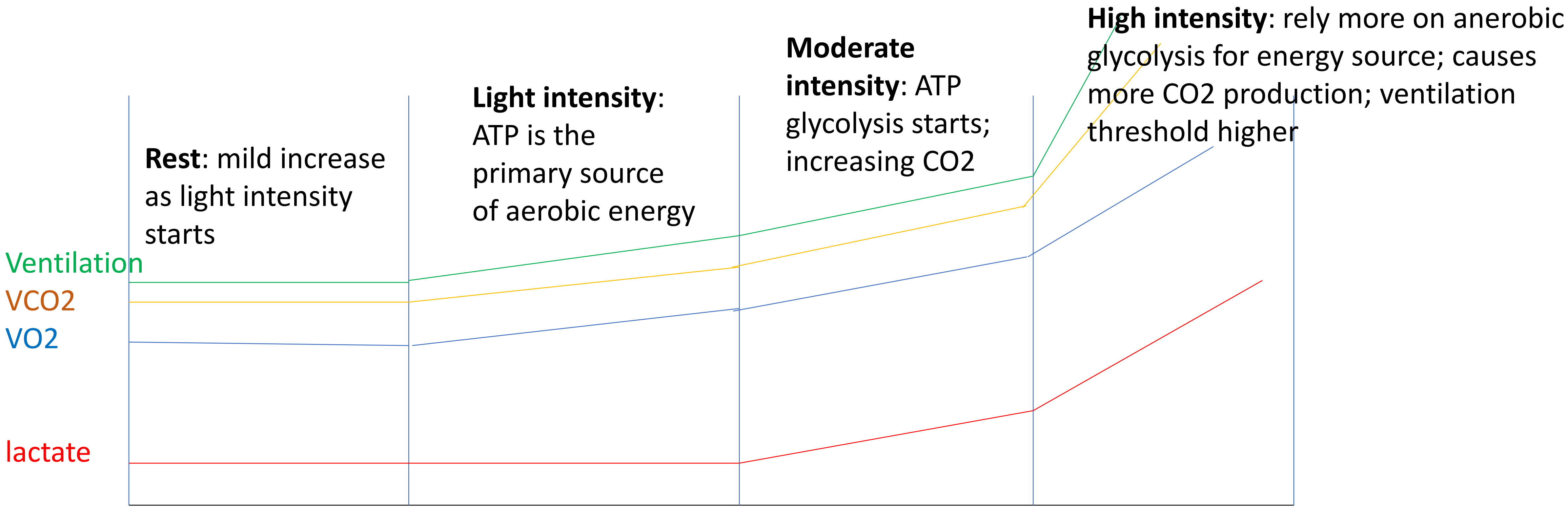
- **Cardiac**: 3, 2, 5, 4
- **Pulmonary**: 1, 4, 7
- **Gas Exchange**: 6, 4, 9
- **Energy Production, Metabolism**: 8

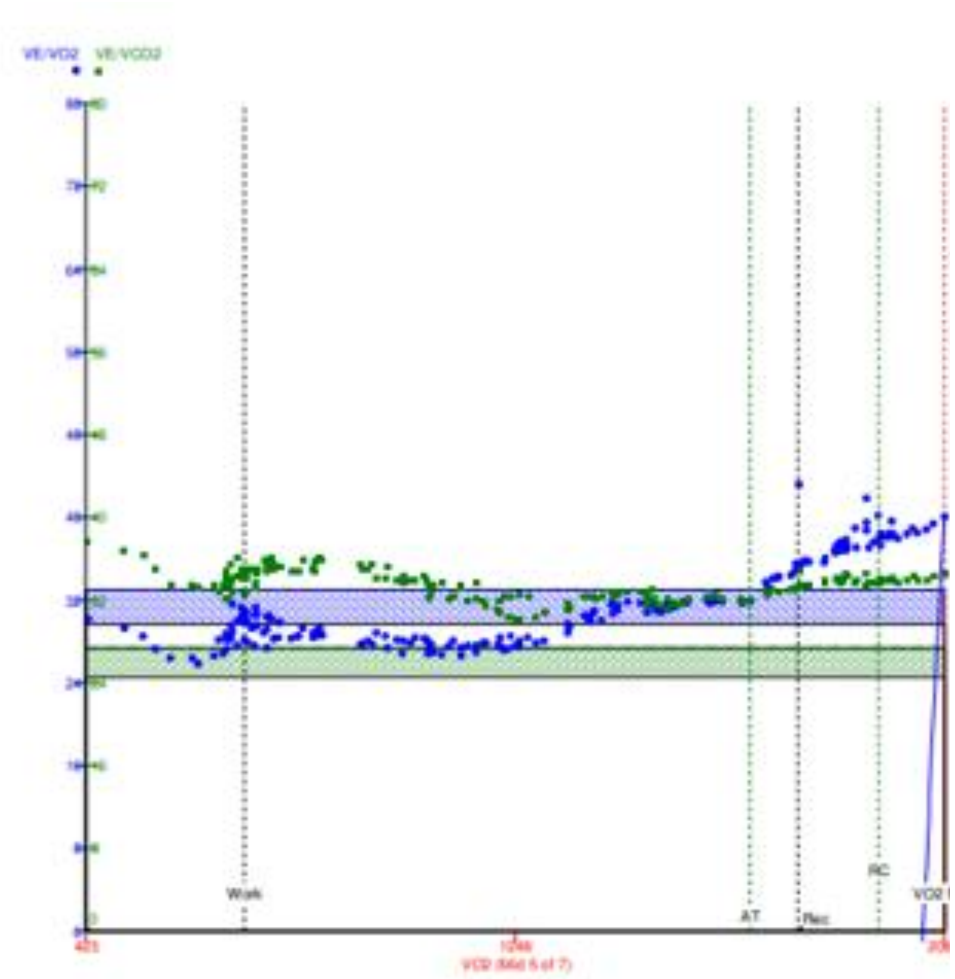
1. VO2 and VCO2 vs. time
2. HR and O2 Pulse vs. time
3. VCO2 and VO2
4. Ve vs. VO2
5. Ve vs. Workrate
6. Ve/VCO2 slope- gas exchange at submaximal exercise
7. PetO2 and PetCO2
8. RER and breathing reserve
9. Breathing pattern (Vt, Ve and rr-breathing frequency)



AT

"During exercise, the oxygen consumption above which aerobic energy production is supplemented by anaerobic mechanisms, causing a sustained increase in lactate and metabolic acidosis, is termed the anaerobic threshold (AT)" Karl Wasserman





	Rest	AT	VO2 Max	Pred	AT / VO2 Max (%)	VO2 Max/Pred (%)
Time (min)	21:30	31:28	33:21			
Ex Time (min)		9:56	11:49			
---- WORK ----						
Work (Watts)	0	120	148	167	81	89
METS	1.2	5.2	6.3	7.2	82	87
VO2WorkSlope (mL/min/wa		9.1	9.9		92	
---- VENTILATION ----						
Vt BTPS (L)	1.08	2.44	2.63		93	
RR (br/min)	11	22	32		71	
VE BTPS (L/min)	12.1	54.2	82.9	112.0	65	74
BR (%)	89.2	51.6	26.0		199	
---- O2 CONSUMPTION ----						
VO2 (mL/kg/min)	4.3	18.1	22.0	25.3	82	87
VO2 (mL/min)	402	1697	2069	2378	82	87
VCO2 (mL/min)	319	1696	2392	2877	71	83
RER	0.79	1.00	1.16		86	
---- CARDIAC ----						
HR (BPM)	93	133	149	163	89	91
VO2/HR (mL/beat)	4	13	14	15	92	95
---- V/Q ----						
PECO2 (mmHg)	22.8	27.0	24.9		108	
PETCO2 (mmHg)	34	39	35		111	
VE/VCO2	38	32	35	27	92	127
VE/VO2	30	32	40	33	80	121
PETO2 (mmHg)	101	103	112		93	
FIO2 (%)	20.82	20.84	20.80		100	
FICO2 (%)	0.13	0.21	0.30		72	

SpO2 (%)	78	97	96		101	
sysBP (mmHg)	105	169	178		95	
diaBP (mmHg)	62	81	98		83	
RatePrsPd SBP*HR/100	97	225	265	310	85	86
Vd/Vt - est	0.29	0.22	0.19		115	

Interpretation

1. **Is the VO2 max > 90% predicted?**
   Yes- Mild limitations allows the pt to achieve close to predicted VO2 max
   No- Limitations are moderate to severe
2. **Is the VR (ventilatory reserve) < 30%?**
   Yes- Ventilatory mechanical limitations exist
   No- No pulmonary limitations
3. **Is the Ve max/VCO2 > 40?**
   Yes- Gas exchange abnormality or anxious patient
   No- No gas exchange limitations
4. **Did the SaO2 or SpO2 decrease more than 4%?**
   Yes- Diffusion-type limitation, possible shunting or V/Q mismatching
   No- No limitations
5. **Is the HR response > 50? (Applies to patients not taking beta blockers)**
   Yes- Cardiac pump problems, cardiomyopathy or physical deconditioning
   No- No cardiac limitations
6. **Is the ratio of the VO2 at AT: actual VO2 max achieved or the predicted VO2 max < 40%?**
   Yes- Circulatory or pump limitation to exercise
   No- No cardiac limitations
7. **Was AT reached?**
   Yes-
   No- Moderate to severe pulmonary limitation, mixed pulmonary and cardiac limitation, or poor patient effort

Value of Biologic Controls

- Monthly commitment to perform test
- Initial test is a full CPET for maximal efforts
- Follow-up controls are submaximal and to be done to verify equipment performance