

Exercise Stress Testing: Cardiovascular or Respiratory Limitation?

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What is exercise?

Physical activity that results in an energy demand above the resting metabolic demand.

“The goal of exercise testing is to evaluate the physiologic response of those organs and systems (e.g., heart, lungs, muscles) involved, to an increase in physical stress.”

ATS/ACCP

“Clinical exercise testing is plagued by a lack of standardization.

.....there is a lack of agreement as to how an exercise test should be carried out, what measurements should be made, how to interpret the results, and what clinical use can be made of them.”

**Norman L. Jones, M.D.
McMaster University
Hamilton, Ontario**

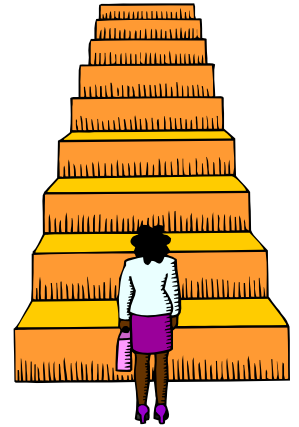
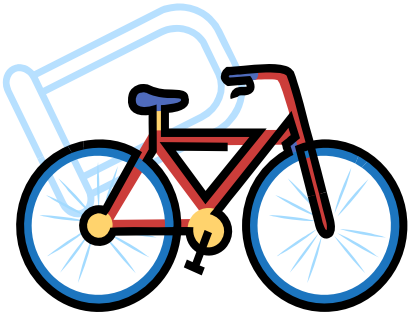
Indications for exercise testing:

- 1) Shortness of breath on exertion**
- 2) Determination of functional capacity**
- 3) Exercise-induced asthma**
- 4) Maximum oxygen consumption studies**
- 5) Evaluation of patients with cardiovascular disease**
- 6) Evaluation of patients with respiratory disease**
- 7) Exercise prescription for pulmonary rehabilitation**



EXERCISE MODALITIES

- Stair Climbing
- Master Two-Step Test
- 6 Minute Walk Test
- Treadmill
- Cycle Ergometer
- Shuttle Walking



EXERCISE PROTOCOLS

Cycle Ergometry

Incremental or ramp

Approximately 10 minutes

Pedaling frequency of 60 rpm

1-3 minutes resting data

1-3 minutes unloaded pedaling

Increase at 5-30 W/minute



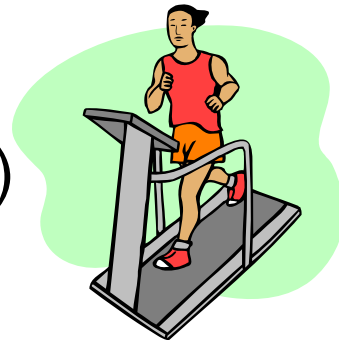
Treadmill

Speed constant and grade is increased (Balke Protocol)

2 mph, 0% grade and then the grade is increased 2-3% every minute

Speed and grade are both increased (Bruce Protocol)

1.7 mph, 10% grade and then increased by 0.8 mph and 2% grade every 3 minutes



Comparison of Cycle versus Treadmill

- $\dot{V}O_2$ max
- Leg muscle fatigue
- Work rate quantification
- Weight bearing in obese
- Noise and artifacts
- Safety issues

Cycle

lower

often limits

yes

less

less

less

Treadmill

higher

less limiting

estimation

more

more

more



During exercise there are increases in:

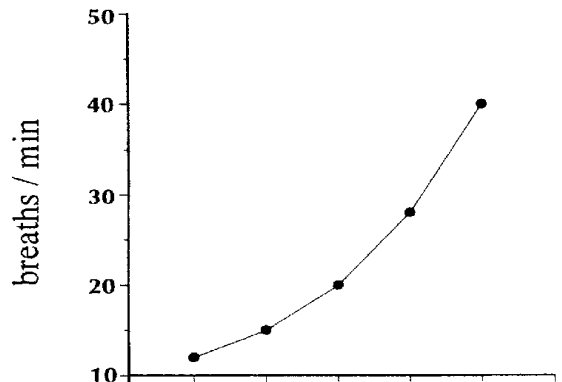
- Heart rate
- Oxygen extraction
- Cardiac output
- Oxygen uptake
- Carbon dioxide output
- Arterial blood pressure
- Minute ventilation
- Alveolar ventilation
- Oxygen pulse
- RQ and RER
- METS



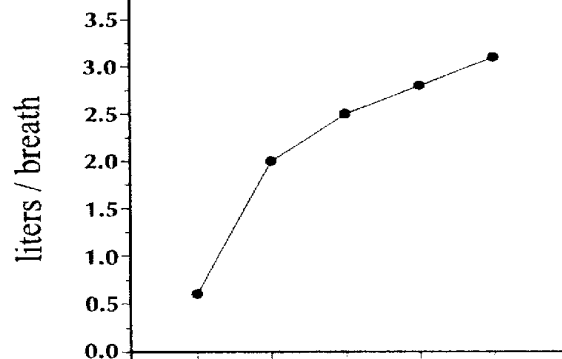
During exercise there are decreases in:

- V_D/V_T

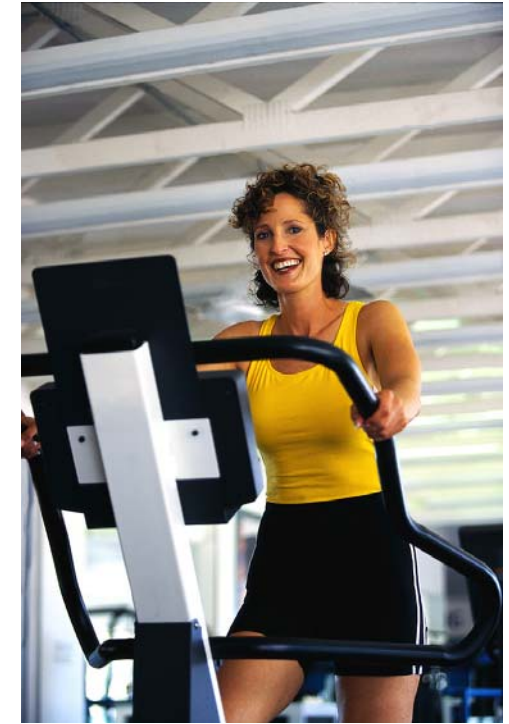
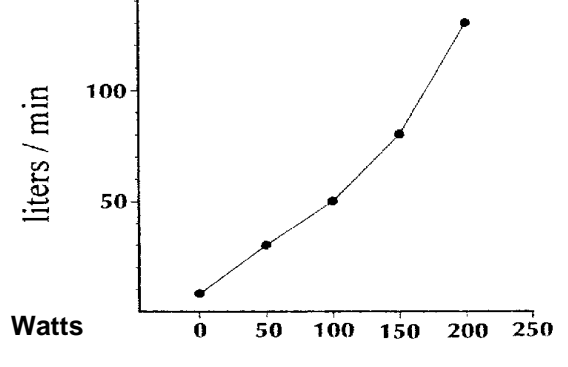
Breathing
Frequency



Tidal
Volume



Minute
Ventilation



f and V_T increase to about 70-80% of peak exercise, thereafter f

V_T plateaus at 50-60% of VC

Respiratory response to incremental work or exercise (Source: Physiology Secrets, 2nd ed., Raff H, Hanley & Belfus, Inc., Philadelphia, 2003)

Maximal Oxygen Uptake (VO_2max)

Represents the highest VO_2 reached for a given form of exercise, as evidenced by a failure for VO_2 to increase further despite an increase in work rate. VO_2max is best index of aerobic capacity and gold standard for cardiopulmonary fitness.

Maximum Oxygen Uptake (VO_2peak)

Represents the highest VO_2 reached for a given, presumed maximal exercise effort.

Generally VO_2max and VO_2peak are used interchangeably.



Oxygen Consumption: the amount of oxygen used per minute

250 mL/min at rest (3.5 mL/min/kg)

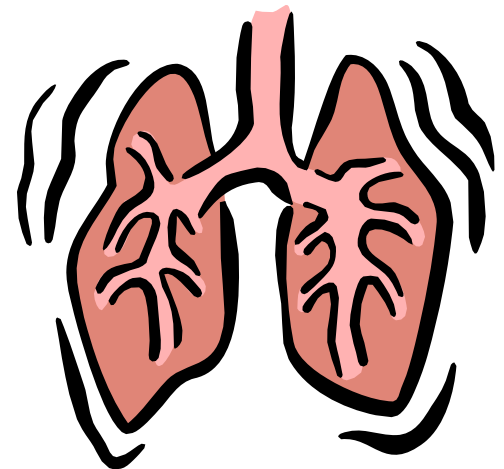
5,000 mL/min at strenuous exercise (>70 mL/min/kg)

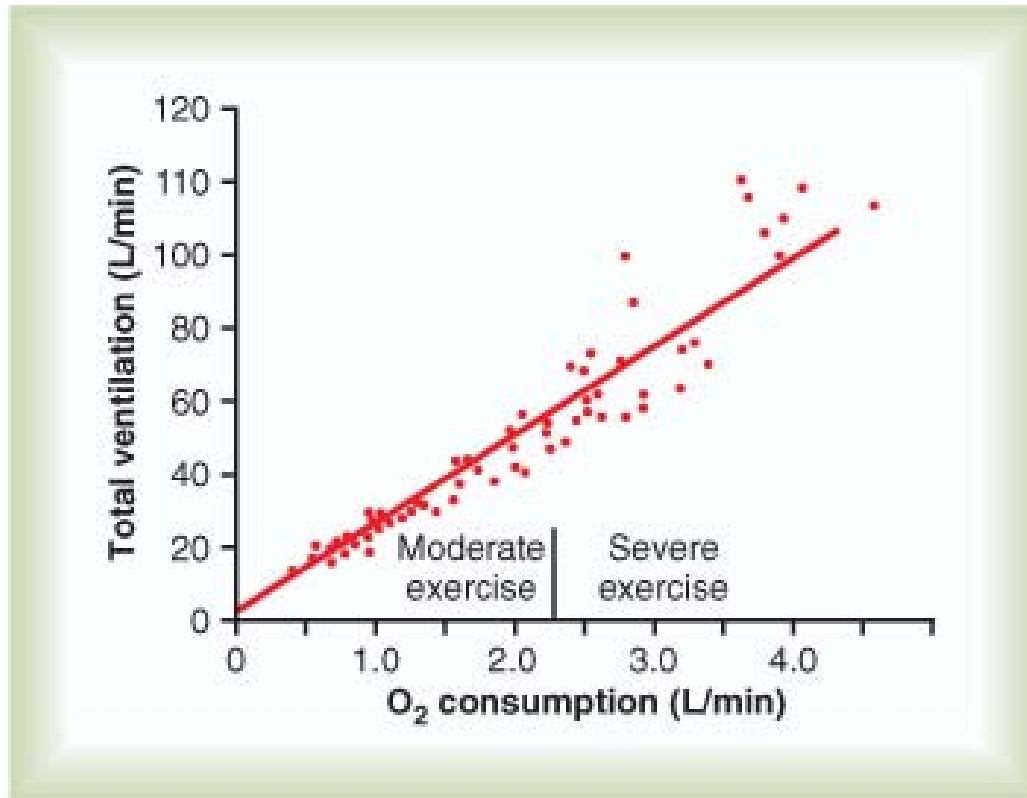
Cost of Ventilation: that portion of total oxygen consumption utilized by the respiratory muscles

2-5% of $\dot{V}O_2$ at rest

>30% of $\dot{V}O_2$ during exercise

“Respiratory steal” phenomenon





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Ventilatory Equivalents

$$\dot{V}_E / \dot{V}O_2$$

$$\dot{V}_E / \dot{V}CO_2$$

Effect of exercise on oxygen consumption and ventilatory rate. (Redrawn from Gray JS: Pulmonary Ventilation and Its Physiological Regulation. Springfield, IL: Charles C Thomas, 1950. Figure 84-6, Guyton, pg. 1061)

ANAEROBIC THRESHOLD

“Exercise VO_2 that marks the transition between no change or little change in arterial lactate concentration and the sustained increase in concentration of lactate.”

ATS/ACCP

- **Lactate Threshold**
- **Lactic Acid Threshold**
- **Gas Exchange Threshold**
- **Ventilatory Threshold**

Estimates the onset of metabolic acidosis caused predominantly by the increased rate of arterial lactate during exercise.



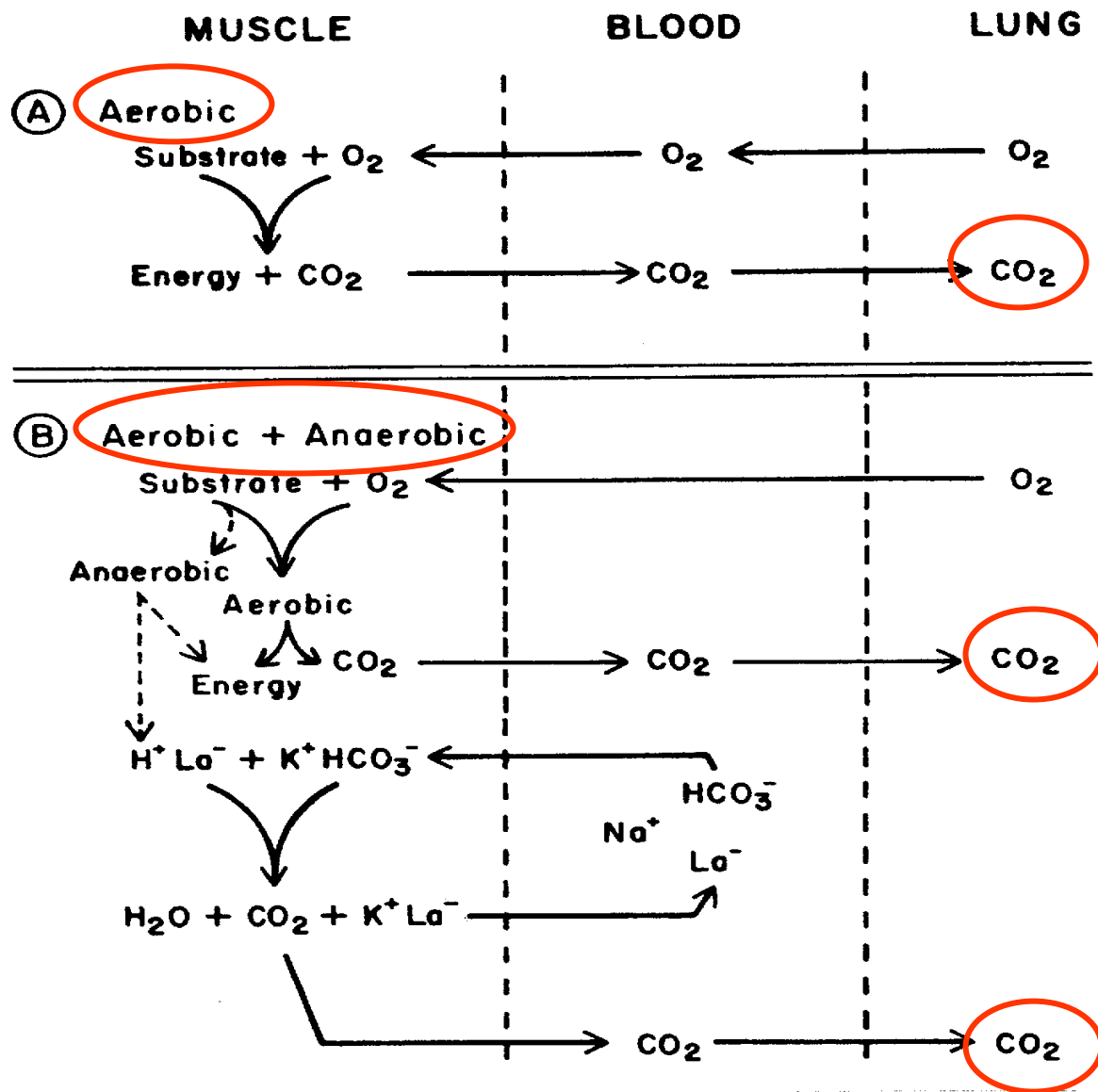


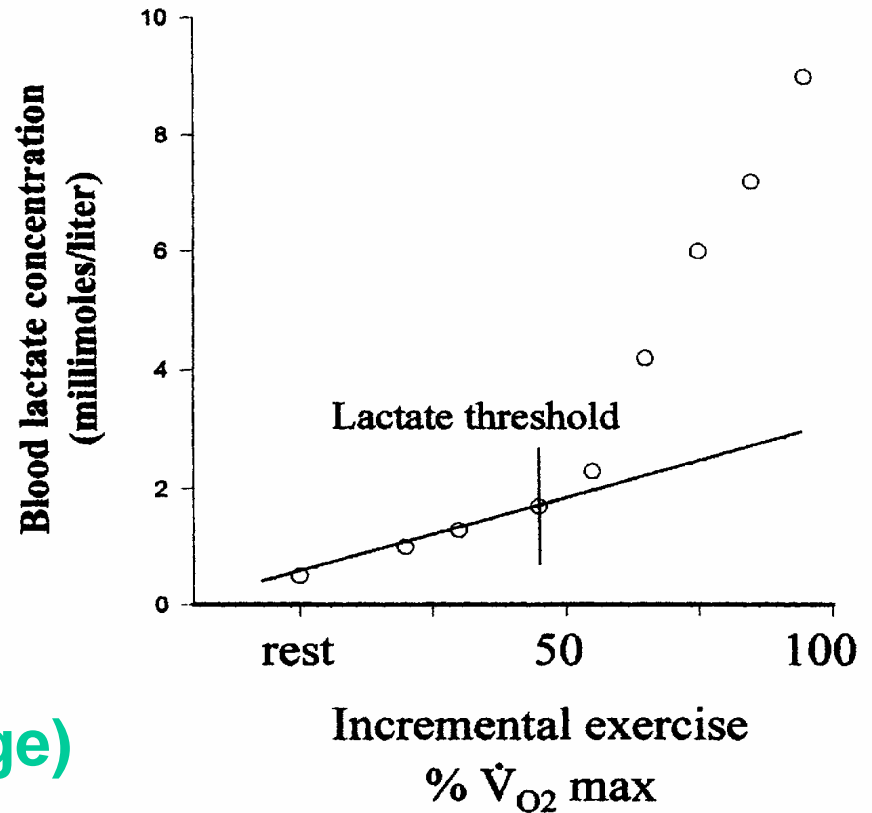
Fig 2-2. Gas Exchange During Aerobic and Anaerobic Exercise (Source: Principles of Exercise Testing and Interpretation, Wasserman et al, Lea & Febiger Publishers, Philadelphia, 1994)

ANAEROBIC THRESHOLD (AT)

AT is generally referenced to the $\dot{V}O_2$ at which the change occurs, i.e., the rate of change in arterial lactate rapidly rises.

Normal:

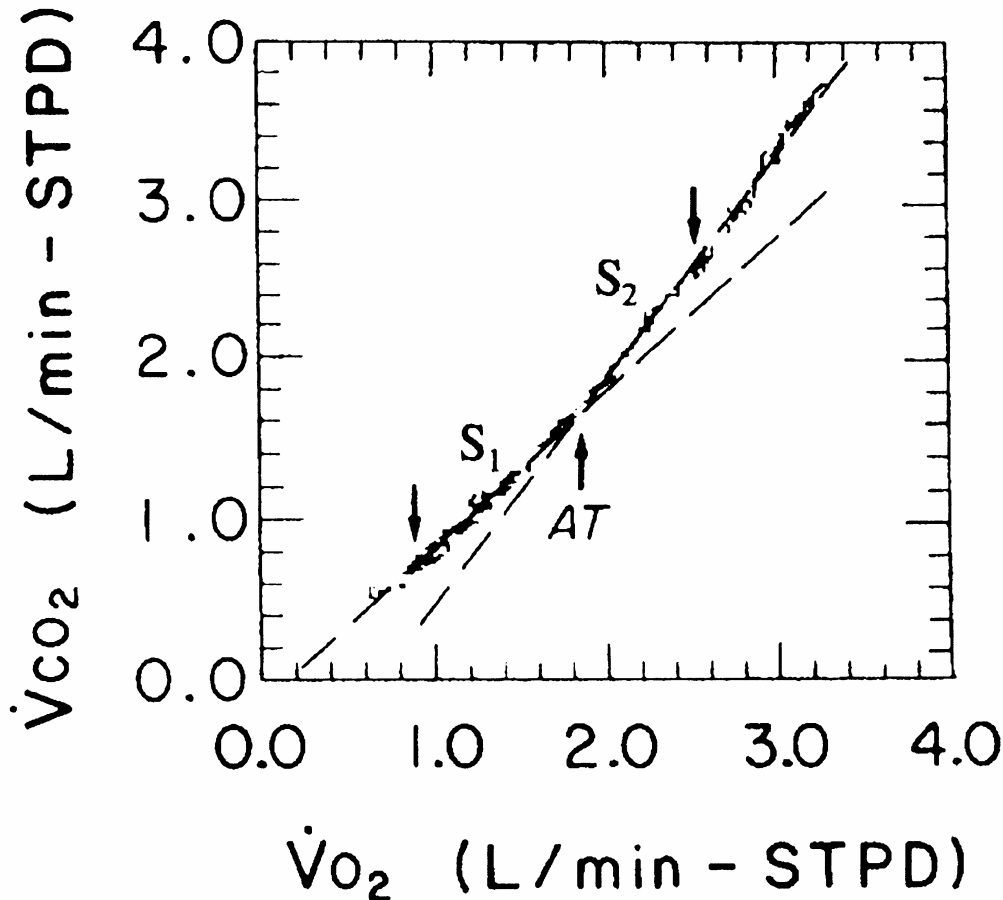
50-60% of $\dot{V}O_2$ (35-80% range)



Blood lactate concentration as a function of incremental exercise (Source: Physiology Secrets, 2nd ed., Raff H, Hanley & Belfus, Inc., Philadelphia, 2003)

V-Slope Method

$\dot{V}O_2$ at which the change in slope of the relationship of $\dot{V}CO_2$ to $\dot{V}O_2$ occurs



$S_1 = \dot{V}CO_2$ increases as a relatively linear function of $\dot{V}O_2$

$S_2 =$ increase in CO_2 due to buffering of lactic acid

Respiratory Quotient (RQ)

- ratio of CO₂ production to oxygen consumption
- used to estimate 'fuels' used for metabolic processes

RQ = 1.0 primarily carbohydrates

RQ = 0.7 carbohydrates and fat

RQ = 0.8 carbohydrates and protein

Respiratory Exchange Ratio (RER)

- ratio of CO₂ output by the lungs to O₂ uptake
- in homeostasis will equal RQ

$$\text{RQ} = \frac{\text{CO}_2 \text{ production}}{\text{O}_2 \text{ consumption}} = \frac{\dot{V}\text{CO}_2}{\dot{V}\text{O}_2}$$

$$\text{RQ} = \frac{0.20 \text{ L/min}}{0.25 \text{ L/min}} = 0.80$$

$$\text{RQ} = \frac{3.85 \text{ L/min}}{3.45 \text{ L/min}} = 1.12$$

$$\text{RER} = \frac{\text{CO}_2 \text{ output}}{\text{O}_2 \text{ uptake}}$$

METS

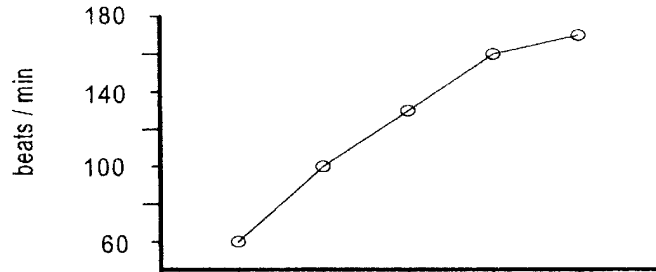
Metabolic equivalent: used to estimate the metabolic cost of physical activity

1 MET = 3.5 mL of O₂ uptake/min/kg

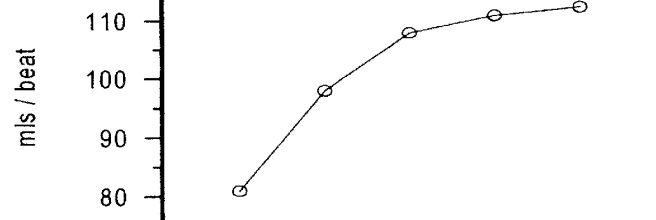
1 MET	rest
4 METS	housework, bowling
6 METS	farming, tennis
8 METS	heavy manual labor, skiing
12 METS	hockey
18 METS	rowing, swimming



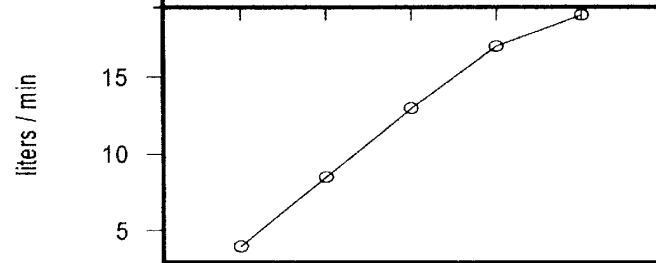
Heart Rate



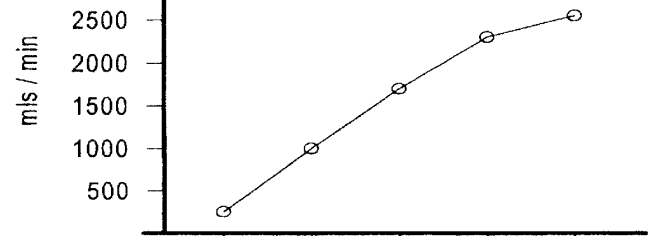
Stroke Volume



Cardiac Output



Oxygen Uptake



Watts 0 50 100 150 200

% $\dot{V}O_2$ max 20 40 60 80 100



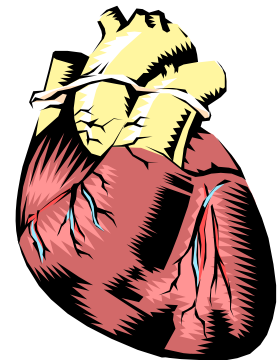
Cardiovascular responses to incremental exercise or work (Source: Physiology Secrets, 2nd ed., Raff H, Hanley & Belfus, Inc., Philadelphia, 2003)

OXYGEN PULSE

$$\text{O}_2 \text{ pulse} = \frac{\dot{V}\text{O}_2}{\text{HR}} = \frac{250 \text{ mL/min}}{72 \text{ bpm}} = 3.5 \text{ mL O}_2/\text{beat}$$

$$\text{O}_2 \text{ pulse} = \frac{\dot{V}\text{O}_2}{\text{HR}} = \frac{3450 \text{ mL/min}}{165 \text{ bpm}} = 20.9 \text{ mL O}_2/\text{beat}$$

Used to 'estimate' stroke volume



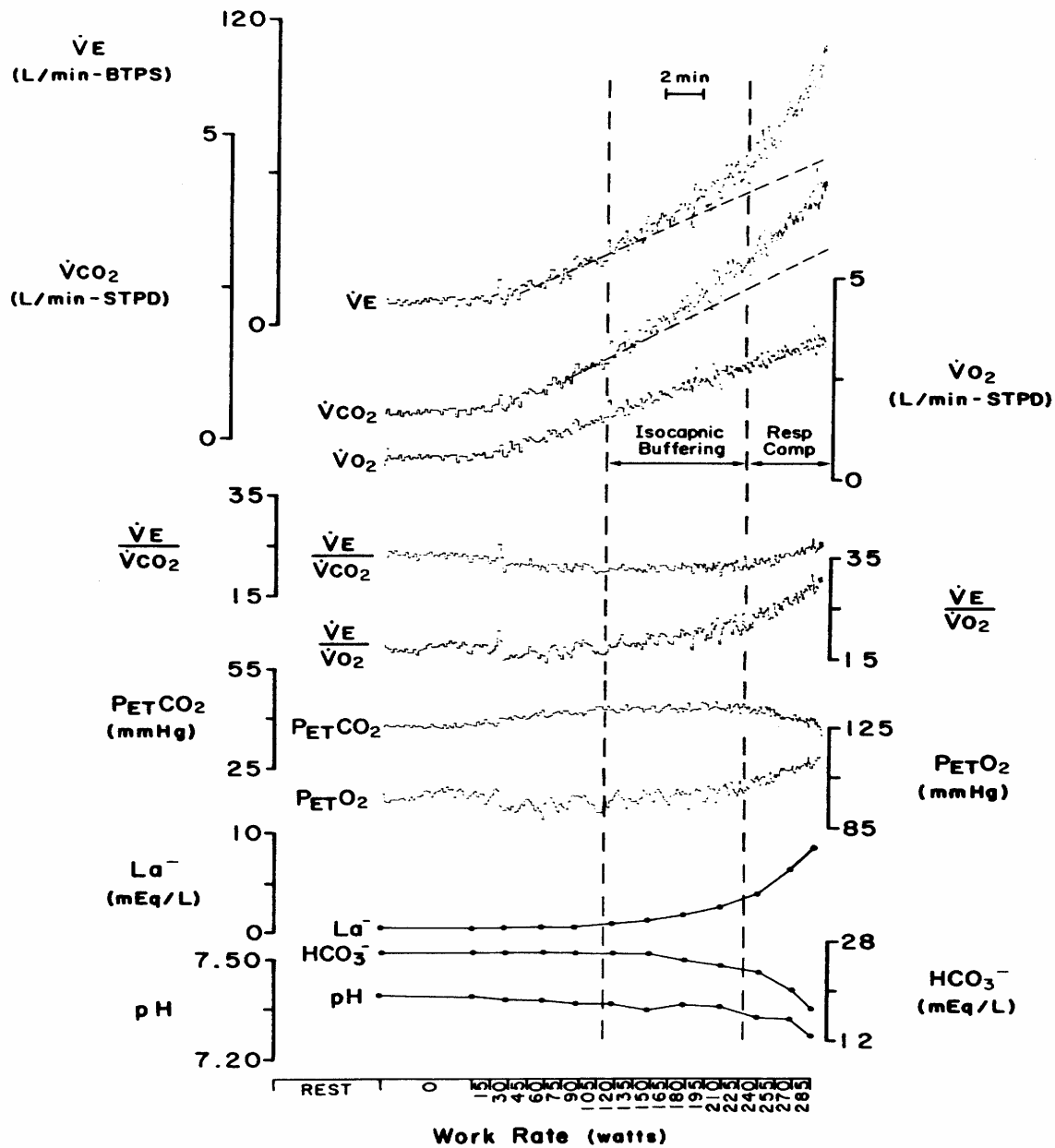


Fig 2-29. Breath-by-Breath Measurements During Exercise (Source: Principles of Exercise Testing and Interpretation, 4th ed., Wasserman et al, LWW Publishers, Philadelphia, 2005)

VENTILATORY LIMITATION

V_E (70-80%)

f (<60)

BR (20-30%)

CARDIOVASCULAR LIMITATION

ECG

Blood pressure response

O₂ pulse

GAS EXCHANGE LIMITATION

SaO₂ or SpO₂ (<4%)

PaO₂ (<10 mmHg)

A-a gradient (<35 mmHg)

Maximal or submaximal stress test?

Subjective;

- ✓ **Chest pain**
- ✓ **Fatigue**
- ✓ **Shortness of breath**

Objective;

- ✓ **Heart rate (>90% of predicted)**
- ✓ **RQ (>1.15)**

Did patient reach AT????

Direct:

- **increase in lactate >4 mmol/L or mEq/L**

Indirect:

- **decrease in $\text{HCO}_3^- >4$ mmol/L or mEq/L**
- **V-slope**
- **RER (RQ) >1.1**

Heart Rate Reserve

HRR (bpm) = Pred HRmax – HR at max

HRR (%) = $\frac{\text{Pred HRmax} - \text{HR at max}}{\text{Pred HRmax}} \times 100$

Predicted Heart Rate = 185

HR at maximum exercise = 165

HRR (bpm) = 185 – 165 = 20 bpm

HRR (%) = $\frac{185 - 165}{185} \times 100 = 11\%$

(Normal = 0)



Breathing Reserve

$$\text{BR (L/min)} = \text{MVV} - \text{V}_{\text{E}}$$

$$\text{BR} = 125 - 100 = 25 \text{ L/min}$$

$$\text{BR (\%)} = \frac{\text{MVV} - \text{V}_{\text{E}}}{\text{MVV}} \times 100$$

$$\text{BR} = \frac{125 - 100}{125} \times 100 = 20\%$$

(Normal = 20-30%)



<i>Variable</i>	<i>Normal</i>	<i>Clinical Significance</i>
VO ₂ max (peak)	>84%	Decreased in heart failure, COPD, ILD, obesity, pulmonary vascular disease, and deconditioned.
AT	>40% VO ₂ max	Decreased in heart failure, COPD, ILD, pulmonary vascular disease, and deconditioned. Normal in obesity.
Heart Rate Heart Rate Reserve	>90% <15 beats/min	Decreased in COPD, obesity, pulmonary vascular disease, and deconditioned. Normal in heart failure.
Oxygen Pulse	>80%	Decreased in heart failure, COPD, ILD, pulmonary vascular disease, and deconditioned. Normal in obesity.
V _E max Frequency Ventilatory or Breathing Reserve	70 – 80% <60 bpm 20 – 30%	Increased or normal in heart failure, COPD, ILD, obesity, pulmonary vascular disease, and deconditioned.

Variable	Normal	Clinical Significance
SaO ₂	<p>≥95%</p> <p>≤4% decrease</p>	<p>Decreased in ILD and pulmonary vascular disease.</p> <p>Normal in heart failure, obesity and deconditioned.</p>
PaO ₂	<p>≥80 mmHg</p> <p>≤10 mmHg fall</p>	<p>Decreased in ILD and pulmonary vascular disease</p> <p>Normal in heart failure, obesity and deconditioned.</p>
P(A-a)O ₂	<35 mmHg	<p>Increased in COPD, ILD, and pulmonary vascular disease.</p> <p>Normal in heart failure and deconditioned.</p>
V _D /V _T	<0.28	Increased in heart failure, COPD, ILD, pulmonary vascular disease, and normal in obesity and deconditioned.
V _E /VCO ₂ (at AT)	<34	<p>Increased in heart failure, COPD, ILD, and pulmonary vascular disease.</p> <p>Normal in obesity and deconditioned.</p>

CASE STUDY #1

62-year-old male; white; height, 175 cm; weight, 84 kg; ideal weight, 78 kg

Clinical Dx: Exertional dyspnea

Medications: None

Reason for testing: Shortness of breath on exertion

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 30 W/min

P_B, 722 mm Hg; P_{I_{O₂}, 142 mm Hg}

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	170	109	Sa _{O₂} , %		
$\dot{V}O_2$, L/min	2.1	98	Sp _{O₂} , %	95	96
$\dot{V}O_2$, ml/kg per min	25.6	91	Pa _{O₂} , mm Hg		
AT, L/min	1.05	N (> 0.86)	Pa _{CO₂} , mm Hg		
$\Delta\dot{V}O_2/\Delta WR$, ml/min/W	10.3	N (> 8.6)	pH		
HR, beats/min	166	98	HCO ₃ ⁻ , mEq/L		
O ₂ pulse, ml/beat	12.6	100	P(A-a)O ₂ , mm Hg		
BP, mm Hg	176/90		V _D /V _T		
\dot{V}_E , L/min	90.7	73	Lactate, mEq/L		
f _R , breaths/min	33	N			
$\dot{V}_E/\dot{V}CO_2$ at AT	34	N			
RER	1.21				

Stop: Dyspnea, 7/10; leg fatigue, 5/10

Normal Exercise Limitation: normal $\dot{V}O_2$, HR, O₂ pulse, \dot{V}_E , f_R, $\dot{V}_E/\dot{V}CO_2$, and SpO₂

CASE STUDY #2

49-year-old female; white; height, 163 cm; weight, 52.6 kg; ideal weight, 63.1 kg

Clinical Dx: Severe dilated cardiomyopathy

Medications: Carvedilol, lisinopril, Lasix, KCl, Coumadin, Paxil, cerivastatin, Premarin, Pepcid

Reason for testing: Evaluation for heart transplantation.

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 20 W/min

P_B, 656 mm Hg; P_{iO₂}, 128 mm Hg

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	80	88	Sa _{O₂} , %	96	95
$\dot{V}O_2$, L/min	0.83	60	Sp _{O₂} , %	95	85
$\dot{V}O_2$, ml/kg per min	15.8	60	Pa _{O₂} , mm Hg	77	84
AT, L/min	0.60	L (> 0.76)	Pa _{CO₂} , mm Hg	35	30
$\Delta\dot{V}O_2/\Delta WR$, ml/min/W	5.1	L (> 8.6)	pH	7.451	7.346
HR, beats/min	166	94	HCO ₃ ⁻ , mEq/L	24	17
O ₂ pulse, ml/beat	5.0	64	P(A-a)O ₂ , mm Hg	13	20
BP, mm Hg	174/87		V _D /V _T	0.43	0.33
$\dot{V}E$, L/min	47	36	Lactate, mEq/L	0.7	7.9
f _R , breaths/min	37	N			
$\dot{V}E/\dot{V}CO_2$ at AT	37	H			
RER	1.28		Stop: Dyspnea, 3/10; leg fatigue, 4-5/10		

Cardiovascular Exercise Limitation: decreased $\dot{V}O_2$ and O₂ pulse, normal $\dot{V}E$ and f_R, increased $\dot{V}E/\dot{V}CO_2$ at AT (i.e., V/Q mismatch)

CASE STUDY #3

66 year-old male; white; height, 175 cm; weight, 61 kg; ideal weight,: 77.5 kg

Clinical Dx: Severe COPD

Medications: Ipratropium bromide, budesonide, salmeterol, as-needed Proventil, Tagamet

Reason for testing: Evaluation of functional capacity and worsening of dyspnea

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 10 W/min

P_B, 656 mm Hg, P_{I_{O₂}, 128 mm Hg}

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	70	65	Sa _{O₂} , %	92	83
\dot{V}_{O_2} , L/min	1.06	66	Sp _{O₂} , %	90	85
\dot{V}_{O_2} , ml/kg per min	17.4	66	Pa _{O₂} , mm Hg	65	55
AT, L/min	0.75	N (> 0.64)	Pa _{CO₂} , mm Hg	38	46
$\Delta\dot{V}_{O_2}/\Delta WR$, ml/min/W	9.3	N (> 8.6)	pH	7.413	7.279
HR, beats/min	141	84	HCO ₃ ⁻ , mEq/L	24	21
O ₂ pulse, ml/beat	7.5	79	P(A-a)O ₂ , mm Hg	20	27
BP, mm Hg	166/72		V _D /V _T	0.45	0.42
\dot{V}_E , L/min	46	121	Lactate, mEq/L	1.4	6.9
f _R , breaths/min	36	N			
\dot{V}_E/\dot{V}_{CO_2} , at AT	44	H			
RER	1.03		Stop: Dyspnea, 10/10		

Ventilatory Exercise Limitation: decreased $\dot{V}O_2$, increased \dot{V}_E (i.e., no ventilatory reserve) with normal f_R, increased $\dot{V}_E/\dot{V}CO_2$ at AT (i.e., V/Q mismatch), decreased SaO₂ and PaO₂ with exercise

CASE STUDY #4

72 year-old male; white; height, 170 cm; weight, 80 kg; ideal weight, 74 kg

Clinical Dx: Idiopathic pulmonary fibrosis

Medications: None

Reason for testing: IPF: assessment of exercise tolerance, evaluate desaturation

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 15 W/min

P_B, 722 mm Hg; P_{I_{O₂}, 142 mm Hg}

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	95	64	SaO ₂ , %	94	80
$\dot{V}O_2$, L/min	1.19	67	PaO ₂ , mm Hg	72	49
$\dot{V}O_2$, ml/kg per min	14.9	62	PaCO ₂ , mm Hg	42	42
AT, L/min	0.80	(> 0.70)	pH	7.39	7.31
HR, beats/min	132	81	P(A-a)O ₂ , mm Hg	24	47
O ₂ pulse, ml/beat	9.0	83	V _D /V _T	0.40	0.40
BP, mm Hg	172/86				
$\dot{V}E$, L/min	57	93			
f _R , breaths/min	42	N			
$\dot{V}E/\dot{V}CO_2$, at AT	49	H			
RER	1.04				

Stop: Dyspnea, 6/10; leg fatigue, 5/10

Ventilatory Exercise Limitation: decreased $\dot{V}O_2$, increased $\dot{V}E$ (i.e., 7% ventilatory reserve) with normal f_R, increased $\dot{V}E/\dot{V}CO_2$ at AT (i.e., V/Q mismatch), decreased SaO₂ and PaO₂ with exercise

CASE STUDY #5

22-year-old male; black; height, 185 cm; weight, 77 kg; ideal weight, 85 kg

Clinical Dx: status post empyema and decortication, deep venous thrombosis, pulmonary embolism

Medications: Warfarin

Reason for testing: Dyspnea on exertion disproportionate to PFTs

Cardiopulmonary Exercise Test

Protocol: Maximal, symptom limited, incremental cycle ergometry, 15 W/min

P_B, 656 mm Hg; P_{I_{O₂}, 128 mm Hg}

Variable	Peak	% Pred	Variable	Rest	Peak
Work rate, W	150	56	Sa _{O₂} , %	91	87
\dot{V}_{O_2} , L/min	1.96	60	Pa _{O₂} , mm Hg	67	58
\dot{V}_{O_2} , ml/kg per min	25.6	60	Pa _{CO₂} , mm Hg	36	29
AT, L/min	1.05	L (> 1.31)	pH	7.393	7.394
$\Delta\dot{V}_{O_2}/\Delta WR$, ml/min/W	9.2	N (> 8.6)	HCO ₃ ⁻ , mEq/L	22	17
HR, beats/min	176	90	P(A-a)O ₂ , mm Hg	19	42
O ₂ pulse, ml/beat	11.1	66	V _D /V _T	0.32	0.35
BP, mm Hg	174/86				
\dot{V}_E , L/min	125	80			
f _R , breaths/min	66	H			
\dot{V}_E/\dot{V}_{CO_2} at AT	41	H			
RER	1.26				

Stop: Dyspnea, 10/10

Cardiovascular with Borderline Ventilatory Exercise Limitation:

decreased \dot{V}_{O_2} and O₂ pulse, normal \dot{V}_E with increased f_R, increased \dot{V}_E/\dot{V}_{CO_2} at AT (i.e., V/Q mismatch), borderline decrease in SaO₂ and PaO₂

Case #1:

A 38 year old male was seen in the Pulmonary Clinic with complaint of shortness of breath on exertion. Pulmonary function tests (spirometry, lung volumes and diffusing capacity) were within normal limits. At rest arterial blood gases were also normal. Chest x-ray was normal. A CPET was ordered on the patient.

Date: 07/13/04

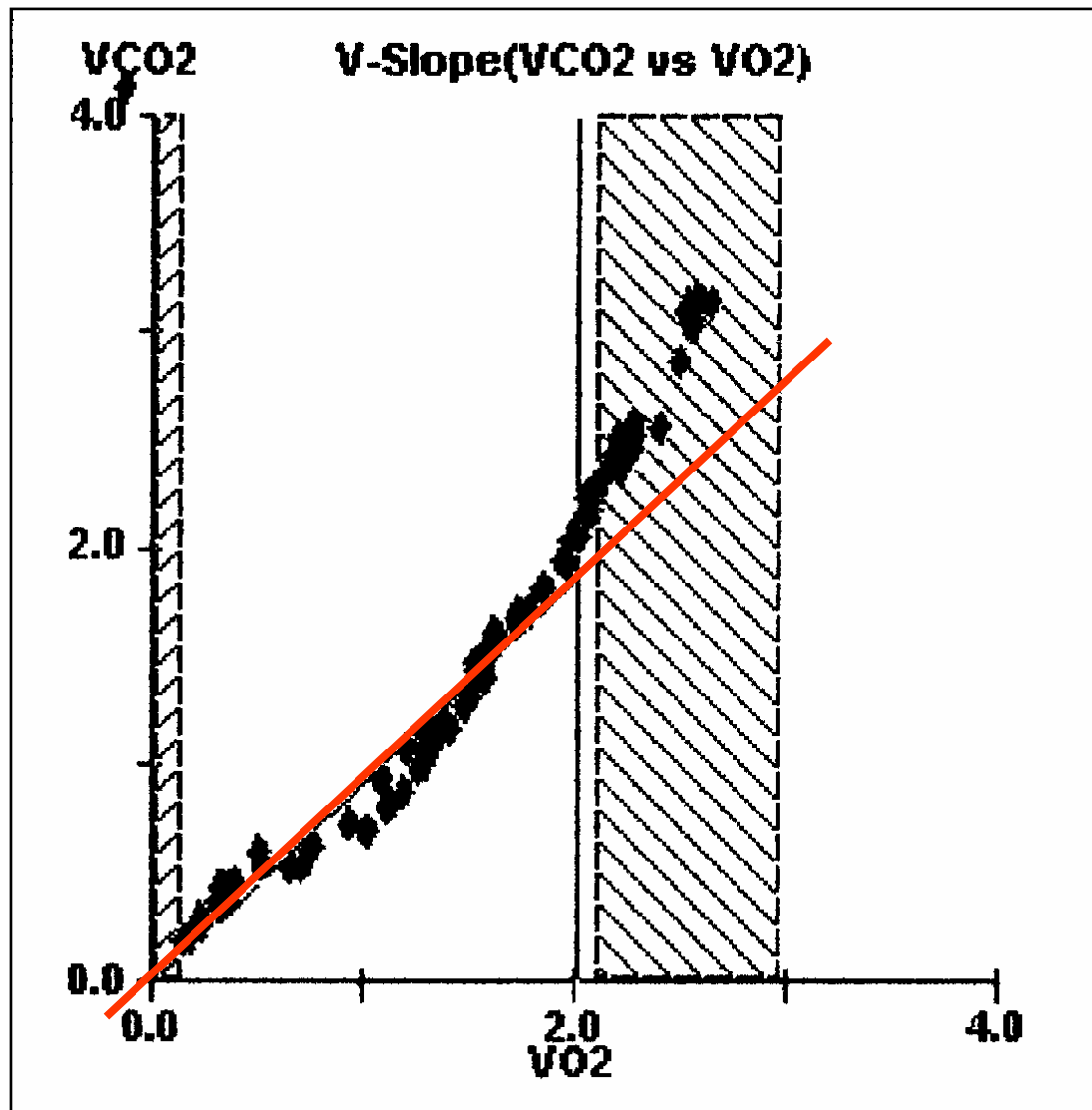
Metabolic Edit —

Time Min	Speed MPH	Grade %	RR BPM	Vt Liters	VE(BTPS) L/min	VO2 L/min	VCO2 L/min	RQ	METS
0.5			13	0.466	6.1	0.152	0.119	0.83	0.6
Test Stage - Exercise									
1.5			14	0.561	7.6	0.197	0.161	0.81	0.7
2.5	1.5		16	0.717	11.9	0.330	0.303	0.91	1.2
3.5	1.9	3.3	23	0.767	17.3	0.554	0.466	0.85	2.0
4.5	2.0	6.0	29	0.879	25.1	0.739	0.700	0.96	2.7
5.5	2.0	9.5	27	1.003	27.2	0.849	0.827	0.97	3.1
6.5	2.5	8.3	29	1.197	35.1	1.048	1.127	1.08	3.9
7.4	2.5	8.2	31	1.130	35.2	0.951	1.082	1.14	3.5
8.5	2.5	10.7	31	1.297	39.5	1.141	1.314	1.15	4.2
9.5	2.5	12.7	34	1.299	44.4	1.206	1.437	1.19	4.5
10.5	2.5	14.4	36	1.352	48.4	1.244	1.532	1.23	4.6
11.5	2.6	16.4	38	1.414	53.3	1.346	1.670	1.24	5.0
12.5	2.5	16.6	42	1.421	59.3	1.423	1.820	1.28	5.3
Test Stage -Recovery									
13.3	1.5	3.3	37	1.332	49.3	1.231	1.585	1.29	4.6

Date: 07/13/04

Metabolic Edit ---

Time Min	VEO2	VECO2	PetO2 mmHg	PetCO2 mmHg	VD/Vt Est	HR BPM	O2 Pulse mL/Beat	SBP mmHg	DBP mmHg
0.5	44	53	94.8	37.6	0.43	57	2.7	142	90
Test Stage - Exercise									
1.5	43	53	100.6	36.7	0.41	59	3.3	142	90
2.5	40	45	105.2	35.8	0.32	69	4.7		
3.5	32	38	101.2	37.1	0.29	86	6.4		
4.5	35	37	104.7	37.0	0.27	98	7.6		
5.5	33	33	103.9	38.9	0.25	108	7.9		
6.5	34	31	106.1	39.4	0.21	123	8.5	160	88
7.4	64	62	109.3	37.9	0.23	131	7.2	160	88
8.5	35	30	107.9	39.8	0.19	138	8.3	174	94
9.5	37	31	110.0	38.3	0.18	144	8.4	188	100
10.5	39	32	112.3	37.0	0.17	154	8.1	185	98
11.5	40	32	113.4	36.0	0.16	157	8.6	184	98
12.5	42	33	115.4	34.4	0.14	163	8.7	184	98
Test Stage -Recovery									
13.3	40	31	112.8	37.2	0.16	156	7.9		



VO_2 at AT = 77%

Name:
 ID:
 Room: Pulmonary Clinic
 Physician: JACOBS, E.

Birth Date: 10/15/66 Age: 38
 Gender: Male Race: Caucasian
 Height(in): 69 Weight(lb): 190
 Diagnosis: Shortness of Breath

Date: 05/10/05
 Technician: B.H.

	Pred	Max	%Pred	Level	PRE	MAX	POST
Speed MPH		4.7		SaO2 %	96.1	95.2	96.7
Grade %		16.5		PO2 mmHg	92.9	88.6	107.3
HR BPM	182	183	101	pH	7.44	7.35	7.36
METS	12.7	8.5	67	PCO2 mmHg	35.2	32.1	30.2
RR BPM	55	49	90	HCO3 meq/L	23.5	17.1	16.6
VO2 L/min	2.858	2.577	90	Hb gm/dL	16.1	17.3	16.9
VO2/kg mL/kg/min	33.1	29.8	90	%HbCO %	1.1	1.1	1.3
RQ	1.20	1.21	101	P(A-a)O2 mmHg	11.4	19.4	2.7
VEO2	30	42	140	Lactate 0.8 MMole/L Rest			
VD/Vt Est	0.18	0.03	19	Lactate 11.3 MMole/L Max Exercise			
O2 Pulse mL/Beat	15.7	14.1	90				
METS WR		14					
VE L/min	144	108	75				
BR %	20-30	25					

The results of the CPET:

- 1) are within normal limits
- 2) reveal a ventilatory limitation to exercise
- 3) reveal a cardiovascular limitation to exercise
- 4) reveal a gas exchange abnormality

Name:
ID:
Room: Pulmonary Clinic
Physician: JACOBS, E.

Birth Date: 10/15/66
Gender: Male
Height(in): 69
Diagnosis: Shortness of Breath

Age: 38
Race: Caucasian
Weight(lb): 190

Date: 05/10/05
Technician: B.H.

	Pred	Max	%Pred	Level	PRE	MAX	POST
Speed MPH		4.7		SaO2 %	96.1	95.2	96.7
Grade %		16.5		PO2 mmHg	92.9	88.6	107.3
HR BPM	182	183	101	pH	7.44	7.35	7.36
METS	12.7	8.5	67	PCO2 mmHg	35.2	32.1	30.2
RR BPM	55	49	90	HCO3 meq/L	23.5	17.1	16.6
VO2 L/min	2.858	2.577	90	Hb gm/dL	16.1	17.3	16.9
VO2/kg mL/kg/min	33.1	29.8	90	%HbCO %	1.1	1.1	1.3
RQ	1.20	1.21	101	P(A-a)O2 mmHg	11.4	19.4	2.7
VEO2	30	42	140	Lactate 0.8 MMole/L Rest			
VD/Vt Est	0.18	0.03	19	Lactate 11.3 MMole/L Max Exercise			
O2 Pulse mL/Beat	15.7	14.1	90				
METS WR		14					
VE L/min	144	108	75				
BR %	20-30	25					

CPET is within normal limits:

V_E 70-80% (75%)

RR or respiratory rate <60 (49)

BR 20-30% (25)

O₂ pulse >10 mL O₂/beat (14.1)

SaO₂ <4% decrease (96.1 to 95.2)

PaO₂ <10 mmHg decrease (92.9 to 88.6)

A-a gradient <35 mmHg (19.4)

Case #2:

A 29 year old male was seen in the Asthma/Allergy Clinic complaining of recent shortness of breath on exertion. Pulmonary function tests revealed normal spirometry and lung volumes, with a mild decrease in the diffusing capacity. At rest arterial blood gases on room air were normal. Chest x-ray was normal. A CPET was ordered on the patient.

Name:
ID:
Room: Asthma / Allergy
Physician: LUSTIG, J.

Birth Date: 07/25/75
Gender: Male
Height(in): 65
Diagnosis: D.O.E.

Age: 29
Race: Hispanic
Weight(lb): 190

Date: 03/29/05
Technician: B.H.

	Pred	Max	%Pred	Level	Pre	Max
Speed MPH		4.0		SaO2 %	95.5	91.9
Grade %		17.0		PO2 mmHg	87.8	77.7
HR BPM	191	189	99	pH	7.39	7.24
METS	13.7	7.3	53	PCO2 mmHg	38.7	39.4
RR BPM	55	52	94	HCO3 meq/L	23.0	16.3
VO2 L/min	2.541	2.199	87	Hb gm/dL	16.3	17.7
VO2/kg mL/kg/min	29.4	25.5	87	%HbCO %	0.6	0.6
RQ	1.20	1.21	101	P(A-a)O2 mmHg	12.5	21.9
VEO2	30	39	129	Lactate 1.1 MMole/L Rest		
VD/Vt Est	0.18	0.10	57	Lactate 11.9 MMole/L Max Exercise		
O2 Pulse mL/Beat	13.3	11.6	87			
METS WR		12.2				
VE L/min	114	85.1	75			
BR %	20-30	25				

The results of the CPET:

- 1) are within normal limits
- 2) reveal a ventilatory limitation to exercise
- 3) reveal a cardiovascular limitation to exercise
- 4) reveal a gas exchange abnormality

Name:
ID:
Room: Asthma / Allergy
Physician: LUSTIG, J.

Birth Date: 07/25/75
Gender: Male
Height(in): 65
Diagnosis: D.O.E.

Age: 29
Race: Hispanic
Weight(lb): 190

Date: 03/29/05
Technician: B.H.

	Pred	Max	%Pred
Speed MPH		4.0	
Grade %		17.0	
HR BPM	191	189	99
METS	13.7	7.3	53
RR BPM	55	52	94
VO2 L/min	2.541	2.199	87
VO2/kg mL/kg/min	29.4	25.5	87
RQ	1.20	1.21	101
VEO2	30	39	129
VD/Vt Est	0.18	0.10	57
O2 Pulse mL/Beat	13.3	11.6	87
METS WR		12.2	
VE L/min	114	85.1	75
BR %	20-30	25	

Level		Pre	Max
SaO2	%	95.5	91.9
PO2	mmHg	87.8	77.7
pH		7.39	7.24
PCO2	mmHg	38.7	39.4
HCO3	meq/L	23.0	16.3
Hb	gm/dL	16.3	17.7
%HbCO	%	0.6	0.6
P(A-a)O2	mmHg	12.5	21.9
Lactate	1.1 MMole/L Rest		
Lactate	11.9 MMole/L Max Exercise		

CPET is reveals a gas exchange abnormality:

V_E 70-80% (75%)

RR or respiratory rate <60 (52)

BR 20-30% (25)

O₂ pulse >10 mL O₂/beat (11.6)

SaO₂ <4% decrease (95.5 to 91.9)

PaO₂ <10 mmHg decrease (87.8 to 77.7)

A-a gradient <35 mmHg (21.9)

Case #3:

A 76 year old female was seen in the Pulmonary Hypertension Clinic with complaints of shortness of breath with mild exertion for at least 6 months. Negative smoking history. Pulmonary function tests revealed mild airflow obstruction on spirometry, normal lung volumes, and a mild decrease in the diffusing capacity. A 6-minute walk test was normal with no desaturation. At rest arterial blood gases on room air revealed slight hypoxemia with normal acid-base status. A CPET was ordered on the patient.

Name:
 ID:
 Room: Pulmonary Clinic
 Physician: Soto, F

Birth Date: 09/03/28
 Gender: Female
 Height(in): 61
 Diagnosis: Pulm Htn

Age: 76
 Race: Caucasian
 Weight(lb): 95

Date: 04/05/05
 Technician: B.H. /M.F.

	Pred	Max	%Pred	Level	Pre	Max	Post
Speed MPH		3.0		SaO2 %	95.1	95.6	95.2
Grade %		9.4		PO2 mmHg	78.7	87.6	83.8
HR BPM	144	145	101	pH	7.47	7.45	7.43
METS		5.3		PCO2 mmHg	38.0	32.5	35.3
RR BPM		36		HCO3 meq/L	27.1	22.1	23.3
VO2 L/min	1.536	0.797	52	Hb gm/dL	13.1	14.3	14.0
VO2/kg mL/kg/min	35.6	18.4	52	%HbCO %	0.6	0.6	0.6
RQ		1.22		P(A-a)O2 mmHg	22.6	20.0	20.6
VEO2		54		Lactate 0.6 MMole/L Rest			
VD/Vt Est	0.18	0.23	130	Lactate 6.5 MMole/L Max Exercise			
O2 Pulse mL/Beat	10.7	5.5	51				
METS WR		5.1					
VE L/min	83.0	43.3	52				
BR %	20-30	48					

The results of the CPET:

- 1) are within normal limits
- 2) reveal a ventilatory limitation to exercise
- 3) reveal a cardiovascular limitation to exercise
- 4) reveal a gas exchange abnormality

Name:
ID:
Room: Pulmonary Clinic
Physician: Soto, F

Birth Date: 09/03/28
Gender: Female
Height(in): 61
Diagnosis: Pulm Htn

Age: 76
Race: Caucasian
Weight(lb): 95

Date: 04/05/05
Technician: B.H. /M.F.

	Pred	Max	%Pred	Level	Pre	Max	Post
Speed MPH		3.0		SaO2 %	95.1	95.6	95.2
Grade %		9.4		PO2 mmHg	78.7	87.6	83.8
HR BPM	144	145	101	pH	7.47	7.45	7.43
METS		5.3		PCO2 mmHg	38.0	32.5	35.3
RR BPM		36		HCO3 meq/L	27.1	22.1	23.3
VO2 L/min	1.536	0.797	52	Hb gm/dL	13.1	14.3	14.0
VO2/kg mL/kg/min	35.6	18.4	52	%HbCO %	0.6	0.6	0.6
RQ		1.22		P(A-a)O2 mmHg	22.6	20.0	20.6
VEO2		54		Lactate 0.6 MMole/L Rest			
VD/Vt Est	0.18	0.23	130	Lactate 6.5 MMole/L Max Exercise			
O2 Pulse mL/Beat	10.7	5.5	51				
METS WR		5.1					
VE L/min	83.0	43.3	52				
BR %	20-30	48					

CPET is reveals a cardiovascular limitation to exercise:

V_E 70-80% (52%)

RR or respiratory rate <60 (36)

BR 20-30% (48)

O₂ pulse >10 mL O₂/beat (5.5)

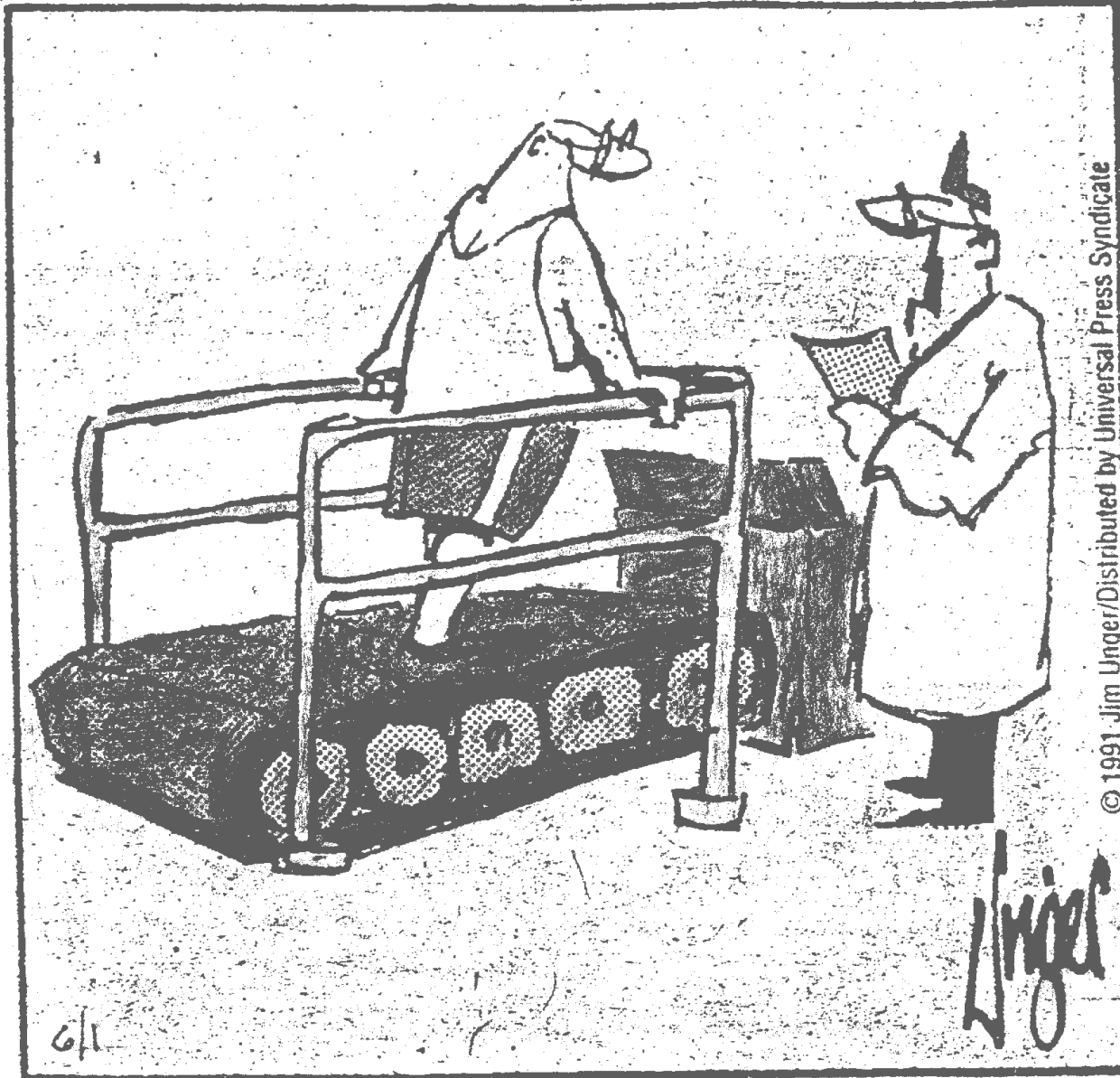
SaO₂ <4% decrease (95.1 to 95.6)

PaO₂ <10 mmHg decrease (78.7 to 87.6)

A-a gradient <35 mmHg (20.0)

REFERENCES

- 1) American Thoracic Society/American College of Chest Physicians: Statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med 167:211-277, 2003.**
- 2) Jones NL: Clinical exercise testing. Philadelphia, WB Saunders Co., 1988**
- 3) Wasserman K, Hansen JE, Sue DY, Stringer WW, Whipp BJ: Principles of exercise testing and interpretation. 4th ed, Philadelphia, LWW, 2005.**
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“What do you mean you’re out of breath? I haven’t switched it on yet!”