An Overview of Exercise Stress Testing And It's Value In Patient Management

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Learning Objectives

- Review Key Definitions
- Describe the Indications and Contraindications
- Examine the Equipment
- Review the Set-up and Procedure
- Evaluate and Interpret Test Results
- Brief Review of 6-Minute Walk Test
- Examine Key References

Definition and Goal of Cardiopulmonary Stress Testing (CPET)

- **Definition: CARDIO-PULMONARY exercise testing** evaluates, characterizes and quantifies the physiologic response of the heart lungs and muscles to an increase in physical stress.
- **Goal:** The goal of CARDIO-PULMONARY exercise testing is to evaluate the physiologic response of the heart lungs and muscles to an increase in physical stress

Major Indications

- Evaluation of dyspnea
  - Distinguish cardiac vs pulmonary vs peripheral limitation vs others
- Detection of exercise-induced bronchoconstriction detection of exertional desaturation
- Detection of exertional desaturation
- Disability determination
- Pulmonary Rehabilitation
  - Exercise intensity/prescription
  - Response to participation
- Pre-op evaluation and risk stratification
- Assess response to therapy

Absolute Contraindications

- Acute MI
- Unstable angina
- Unstable arrhythmia
- Acute endocarditis, myocarditis, pericarditis
- Syncope
- Severe, symptomatic Atrial Stenosis
- Uncontrolled CHF
- Acute PE, DVT
- Respiratory failure
- Uncontrolled asthma
- $SpO_2 < 88\%$ on R/A

Relative Contraindications

- Left main or 3-V CAD
- Severe arterial HTN (>200/120)
- Significant pulmonary HTN
- Tachyarrhythmia, bradyarrhythmia
- High degree AV block
- Hypertrophic cardiomyopathy
- Electrolyte abnormality
- Moderate stenotic valvular heart disease
- Advanced or complicated pregnancy
- Orthopedic impairment

Screening & Initial Evaluation

- HISTORY: tobacco use, medications, tolerance to normal physical activities, any distress symptoms, contraindicated illnesses
- PHYSICAL EXAM: height, weight, assessment of heart, lungs, peripheral pulses, blood pressure
- EKG
- PULMONARY FUNCTION TESTS: spirometry, lung volumes, diffusing capacity, arterial blood gases

Prior to Test

- Wear loose fitting clothes, low-heeled or athletic shoes
- Abstain from coffee and cigarettes at least 2 hours before the test
- Continue maintenance medications
- May eat a light meal at least 2 hours before the test

Exercise Modalities

- Advantages of cycle ergometer
  - Cheaper
  - Safer - Less danger of fall/injury
  - Can stop anytime
  - Direct power calculation
  - Independent of weight
  - Holding bars has no effect
  - Little training needed
  - Easier BP recording, blood draw
  - Requires less space - less noise
- Advantages of treadmill
  - Attain higher VO_2
  - More functional

Equipment & Instrumentation

- Treadmill or cycle ergometer can be used for exercise
  - Cycle preferred because:
    - Ease of measurements (ABGs, BP)
    - Better patient safety (falling not likely)
    - Power can be directly measured
- Ability to continuously monitor and print 12-lead ECG
- Manual or automatic BP device
- Pulse oximeter

Equipment & Instrumentation (cont.)

- Gas analyzers for O_2 and CO_2
  - Mass Spectrometer – gold standard
- Breathing valves
- Ability to measure volume

Treadmill with Computerized ECG and Controller

(Courtesy Medical Graphics Inc., St Paul, Minn.)

Electronically Braked Cycle Ergometer

(Courtesy Medical Graphics Inc., St Paul, Minn.)

Summary of the Procedure

- After screening, the patient is connected to monitoring equipment, including BP, HR, RR, inspired FIO_2 and exhaled CO_2, VT and Minute Ventilation.
- They are then subjected to and increasing workload, per a specified protocol.
  - The Bruce protocol: Multiple exercise stages of three minutes each. At each stage, the gradient and speed of the treadmill are elevated to increase **work output, called METS**. Stage 1 of the Bruce protocol is performed at 1.7 miles per hour and a 10% gradient. Stage 2 is 2.5 mph and 12%, while Stage 3 goes to 3.4 mph and 14%.
- Parameters are measured at each step of the protocol and calculations are then done, which are then interpreted.
- The test is halted if the patient can not continue per the protocol or if adverse responses are noted.

Key Features of the Test

- Symptom-limited exercise test
- Measures airflow, SpO_2 , and expired oxygen and carbon dioxide
- Allows calculation of peak oxygen consumption, anaerobic threshold

Cardiopulmonary Exercise Testing—Work Unit=MET

- Standard work unit used for exercise testing is the **metabolic equivalent of task (MET)**: 1 MET = 3.5 mL O_2 consumption/kg of body weight, about equal to normal resting O_2 consumption/minute.
- MET levels are varied during exercise by altering treadmill speeds and inclinations. Most protocols increase exercise intensity by 1–2 METs at each step-up in workload.

Indications to Terminate

- Patient's request: fatigue, dyspnea, pain
- Ischemic ECG changes
  - 2 mm ST depression
  - Chest pain suggestive of ischemia
  - Significant ectopy
- 2 nd or 3rd degree heart block
- BP sys >240-250,
- BP dias >110-120
- Fall in BPsys >20 mmHg
- $SpO_2 < 85\%$

Mechanism to Exercise Limitation

- **Pulmonary**
  - Ventilatory impairment
  - Respiratory muscle dysfunction
  - Impaired gas exchange
- **Cardiovascular**
  - Reduced stroke volume
  - Abnormal HR response
  - Circulatory abnormality
  - Blood abnormality
- **Peripheral**
  - Inactivity - Atrophy
  - Neuromuscular dysfunction
  - Malnutrition
- **Other**- Perceptual, Motivational, Environmental

CPET Measurements

- Work
- VO_2
- VCO_2
- HR
- ECG
- BP
- RR
- SpO_2
- Anaerobic Threshold (AT)
- ABG Lactate
- Dyspnea

Pulmonary Parameters

- MINUTE VENTILATION
  - NORMAL = 5 – 6 liters/ min --AT EXERCISE = 100 liters/min
  - Increase is due to stimulation of the respiratory centers by brain motor cortex, joint propioceptors and chemoreceptors
  - ANAEROBIC THRESHOLD (AT) the minute ventilation increases more than the workload
- TIDAL VOLUME : NORMAL = 500 ml
  - DURING EXERCISE = 2.3 – 3 liters
  - Increases early in the exercise
- BREATHING RATE
  - NORMAL = 12 – 16 / min AT EXERCISE = 40 – 50 / min
- DEAD SPACE / TIDAL VOLUME ratio
  - NORMAL = 0.20 – 0.40 -- AT EXERCISE = 0.04 – 0.20
  - Decrease is due to increased tidal volume with constant dead space

Pulmonary Parameters (Cont.)

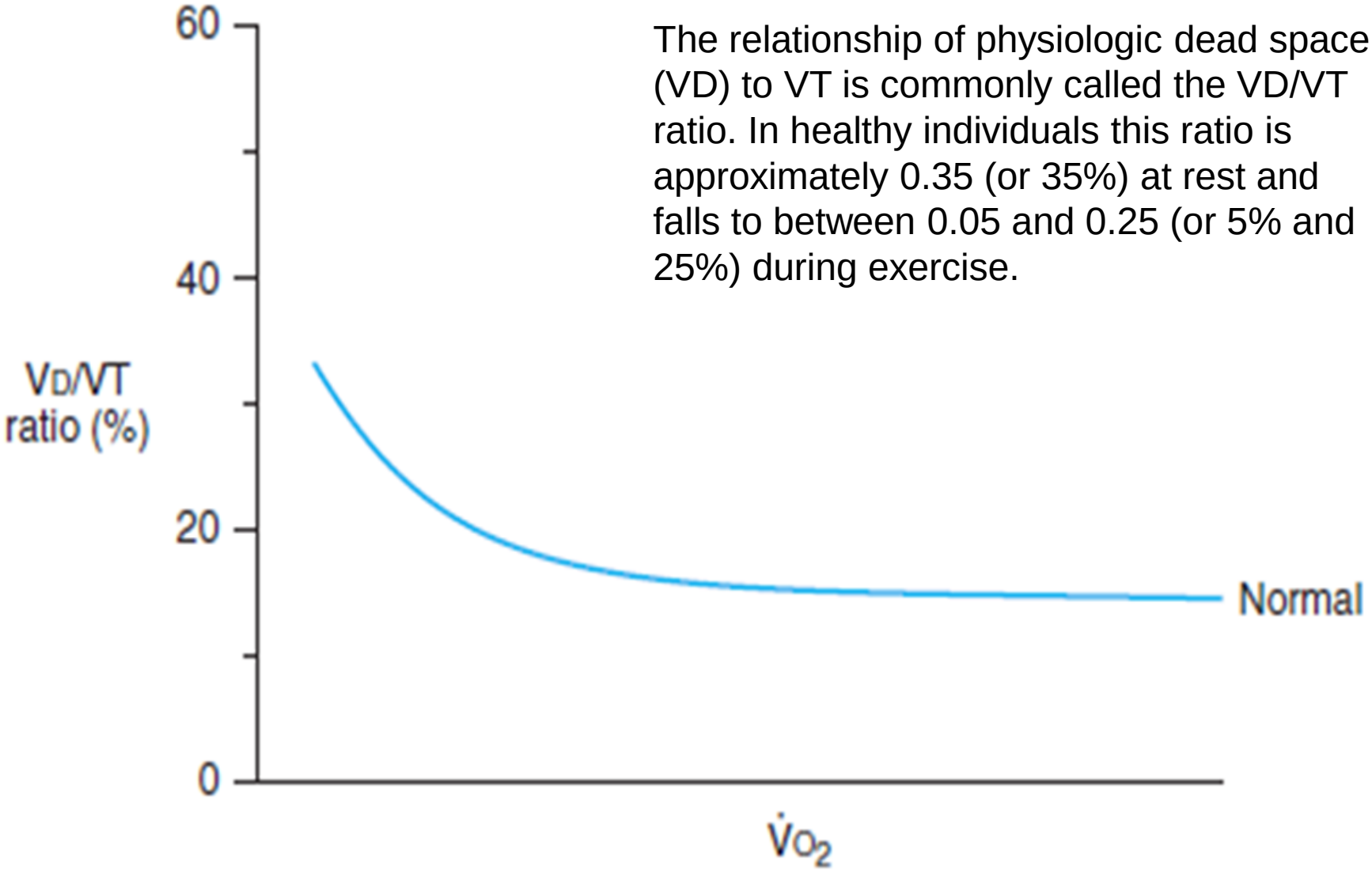
- PULMONARY CAPILLARY BLOOD TRANSIT TIME NORMAL = 0.75 second
  - AT EXERCISE = 0.38 second
  - Decrease is due to increased cardiac output
- ALVEOLAR-ARTERIAL OXYGEN DIFFERENCE
  - NORMAL = 10 mm Hg --AT EXERCISE = 20 – 30 mm Hg
  - Changes very little until a heavy workload is achieved
- OXYGEN TRANSPORT
  - Increase in temperature, PCO_2 and relative acidosis in the muscles -> increase in release of Oxygen by blood for use by the tissues for metabolism.

Cardiovascular Parameters

- CARDIAC OUTPUT NORMAL = 4 – 6 liters / min
  - AT EXERCISE = 20 liters / min
  - increase is linear with increase in workload during exercise until the point of exhaustion.
- STROKE VOLUME NORMAL = 50 – 80 ml
  - AT EXERCISE = double
  - Increase is linear with increase in workload
- HEART RATE NORMAL = 60 – 100 /min AT EXERCISE = 2.5 – 4 times the resting HR
  - HR max is achieved just prior to total exhaustion, physiologic endpoint of an individual
  - HR max = 220 – age or HR max = 210 – (0.65 x age)
- OXYGEN PULSE= VO_2/ HR NORMAL = 2.5 – 4 ml O_2 / heartbeat
  - AT EXERCISE = 10 – 15 ml
  - With increasing muscle work during exercise, each heart contraction must deliver a greater quantity of oxygen out to the body
- BLOOD PRESSURE DURING EXERCISE:
  - Systolic BP increases (to 200 mm Hg)
  - Diastolic BP is relatively stable (up to 90 mmHg)
  - Increase in Pulse Pressure (difference between Systolic and Diastolic pressures)
- ARTERIAL – VENOUS OXYGEN CONTENT DIFFERENCE
  - mL of O_2 / 100 ml of blood
  - NORMAL = 5 vol %
  - AT EXERCISE = 2.5 – 3 times higher the increase is due to the greater amounts of Oxygen that are extracted by the working muscle tissue

Metabolic Parameters

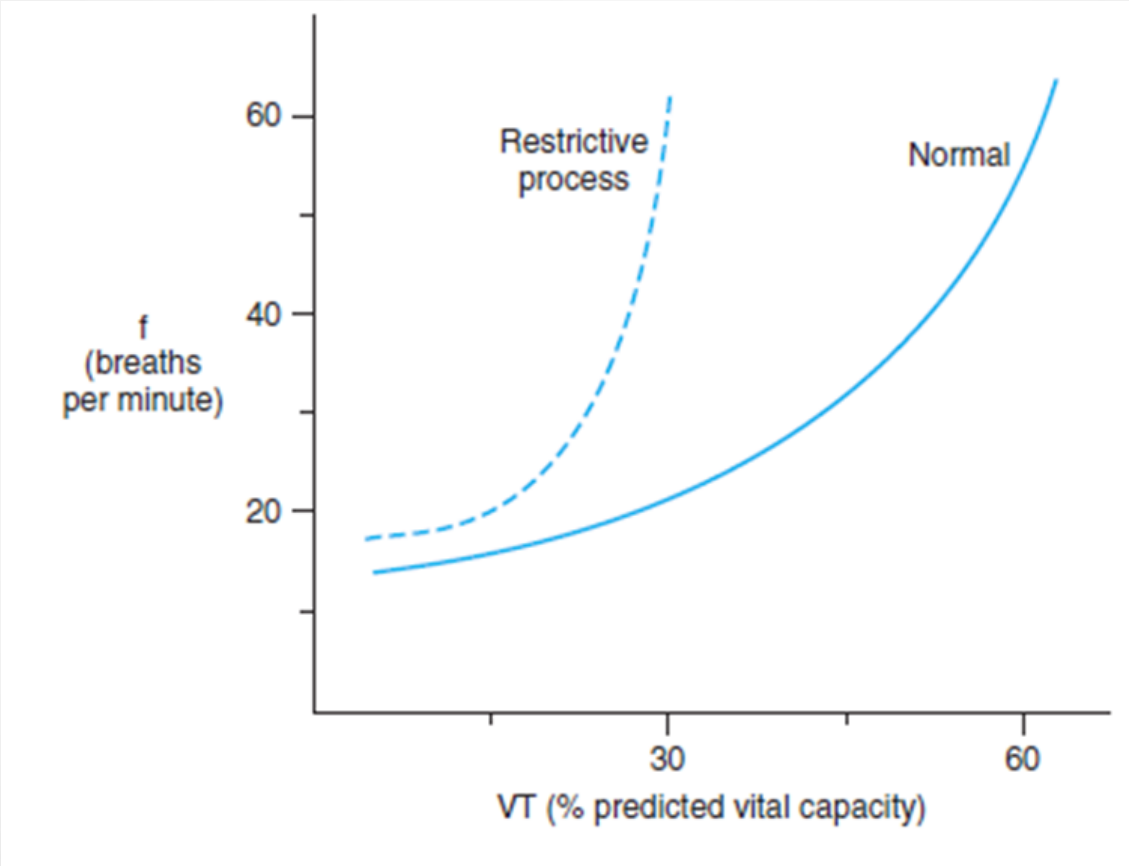
- OXYGEN CONSUMPTION
  - NORMAL = 250 ml / min 3.5 – 4 ml / min / kg
  - Increases directly with the level of muscular work until exhaustion occurs and until individual reaches VO_2max
  - NORMAL RANGE = 1,700 – 5,800 ml / min
- CARBON DIOXIDE PRODUCTION
  - NORMAL = 200 ml / min 2.8 ml / min / kg
  - AT EXERCISE initial phase, increases at same rate as VO_2
  - Once Anaerobic Threshold (AT) is reached, increases at a faster rate than VO_2 due to increased acid production
- ANAEROBIC THERSHOLD (AT)
  - NORMAL: occurs at about 60% of VO_2 max
  - Followed by breathlessness, burning sensation begins in working muscles
- RESPIRATORY QUOTIENT (RQ)
  - RESTING LEVEL = 0.8
  - AT = 1.0 or more may exercise for a short time on 1.5
  - RER = CO_2 produced / O_2 consumed = VCO_2 / VO_2

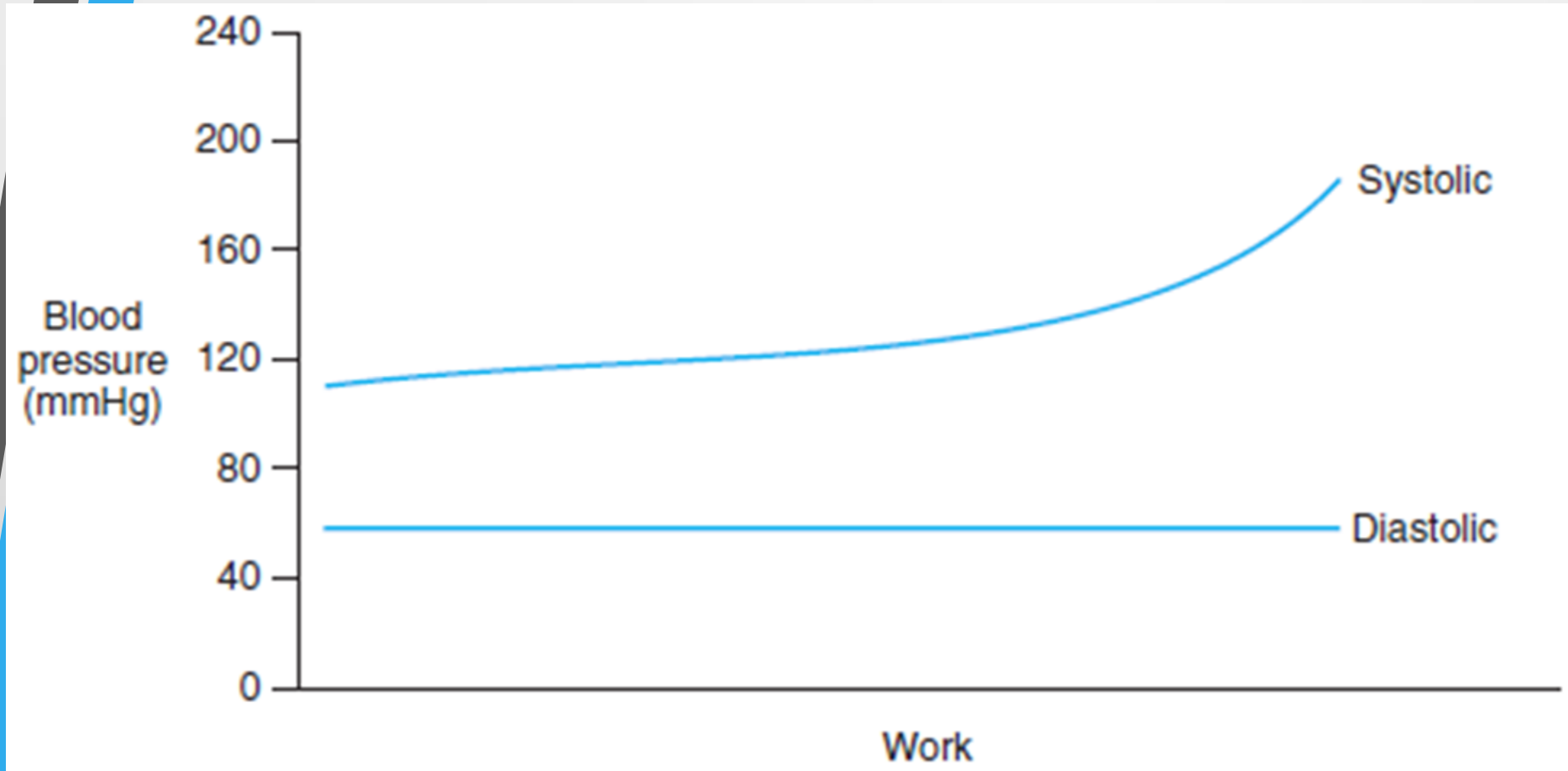


The relationship of physiologic dead space (VD) to VT is commonly called the VD/VT ratio. In healthy individuals this ratio is approximately 0.35 (or 35%) at rest and falls to between 0.05 and 0.25 (or 5% and 25%) during exercise.

The VT increases up to approximately 60% of the patient's VC and levels off, while f increases up to 50 to 60 breaths/min.

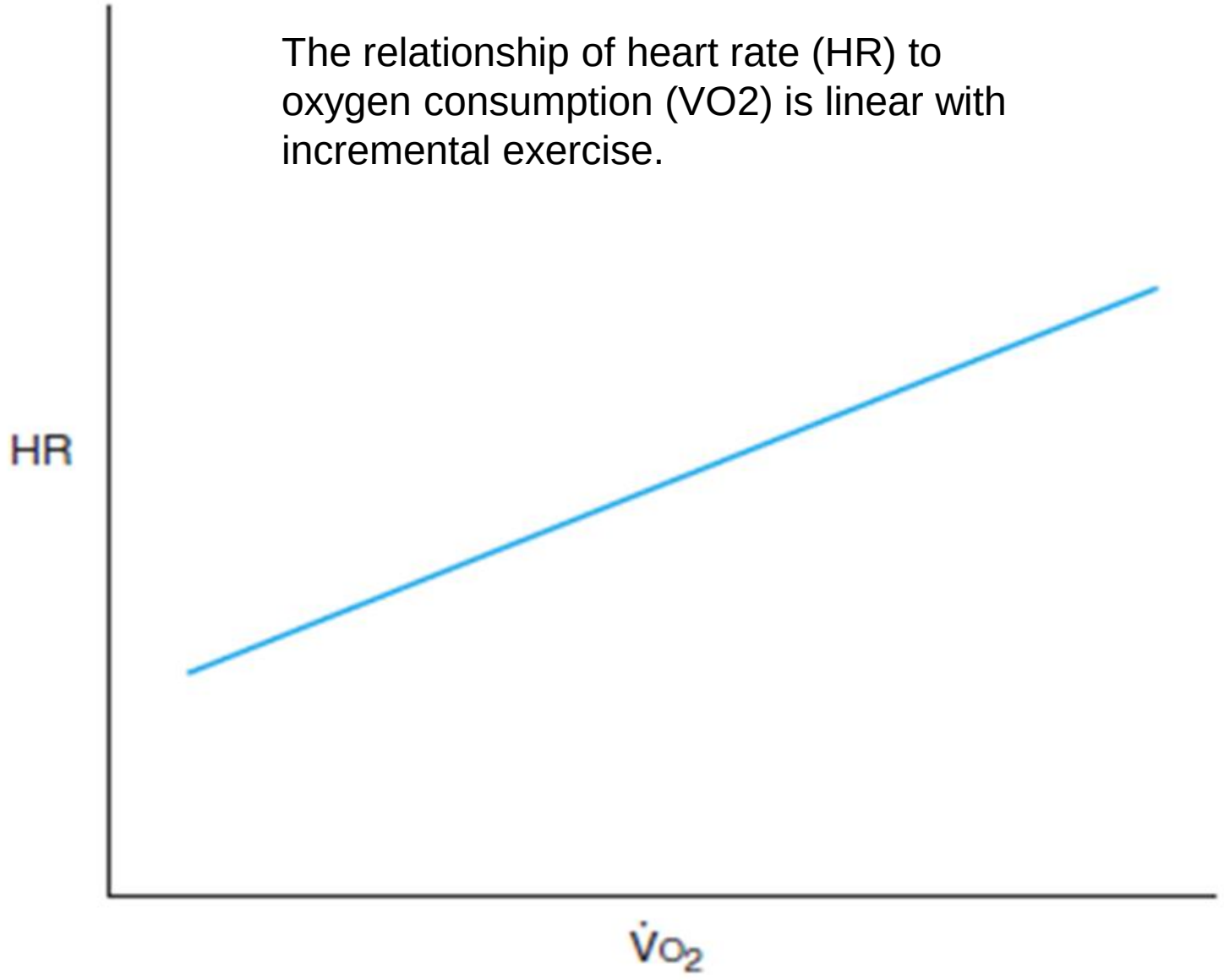
In patients with restrictive processes the relationship between f and VT is shifted upward and to the left (dashed line). This is a result of their rapid shallow breathing pattern.

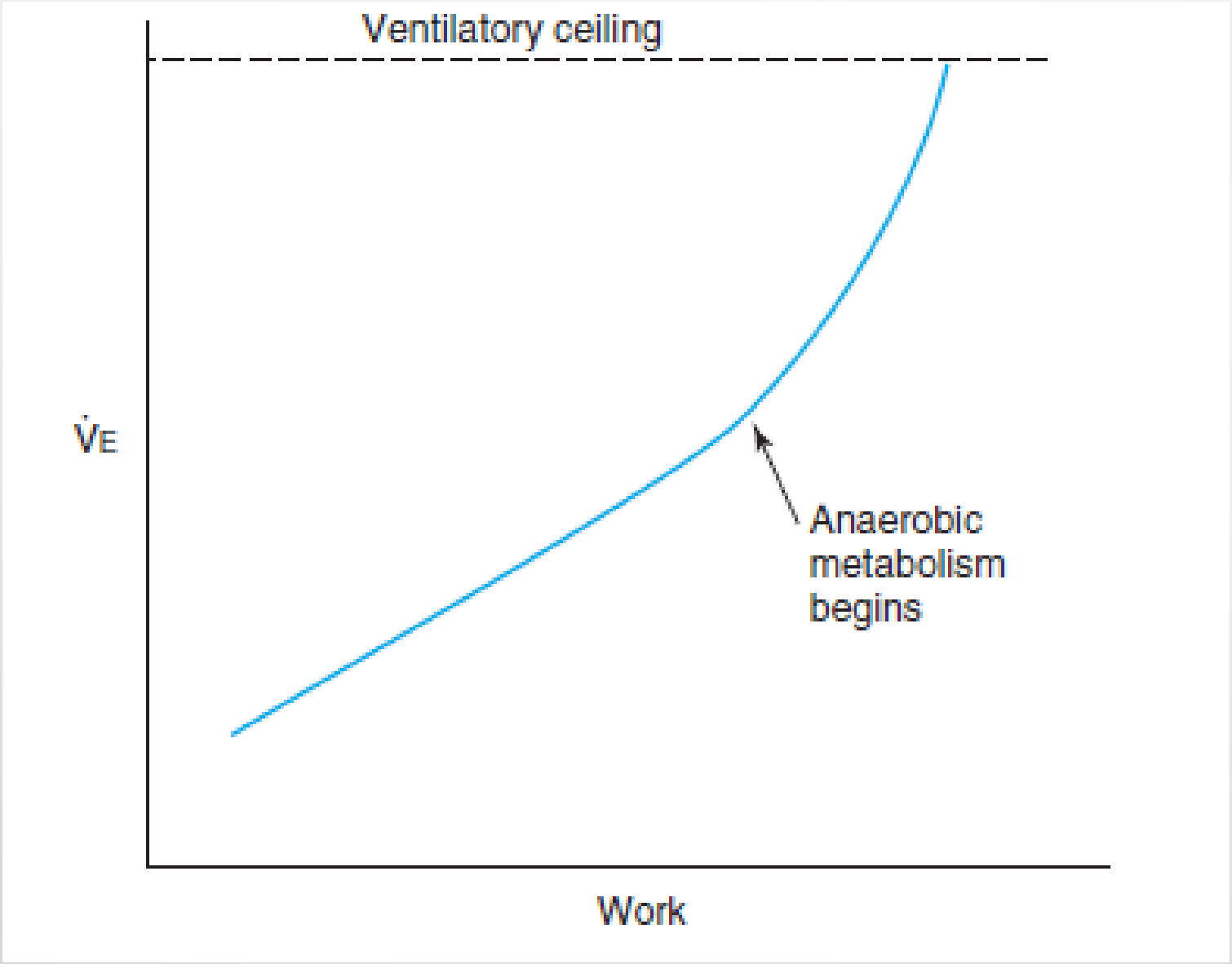




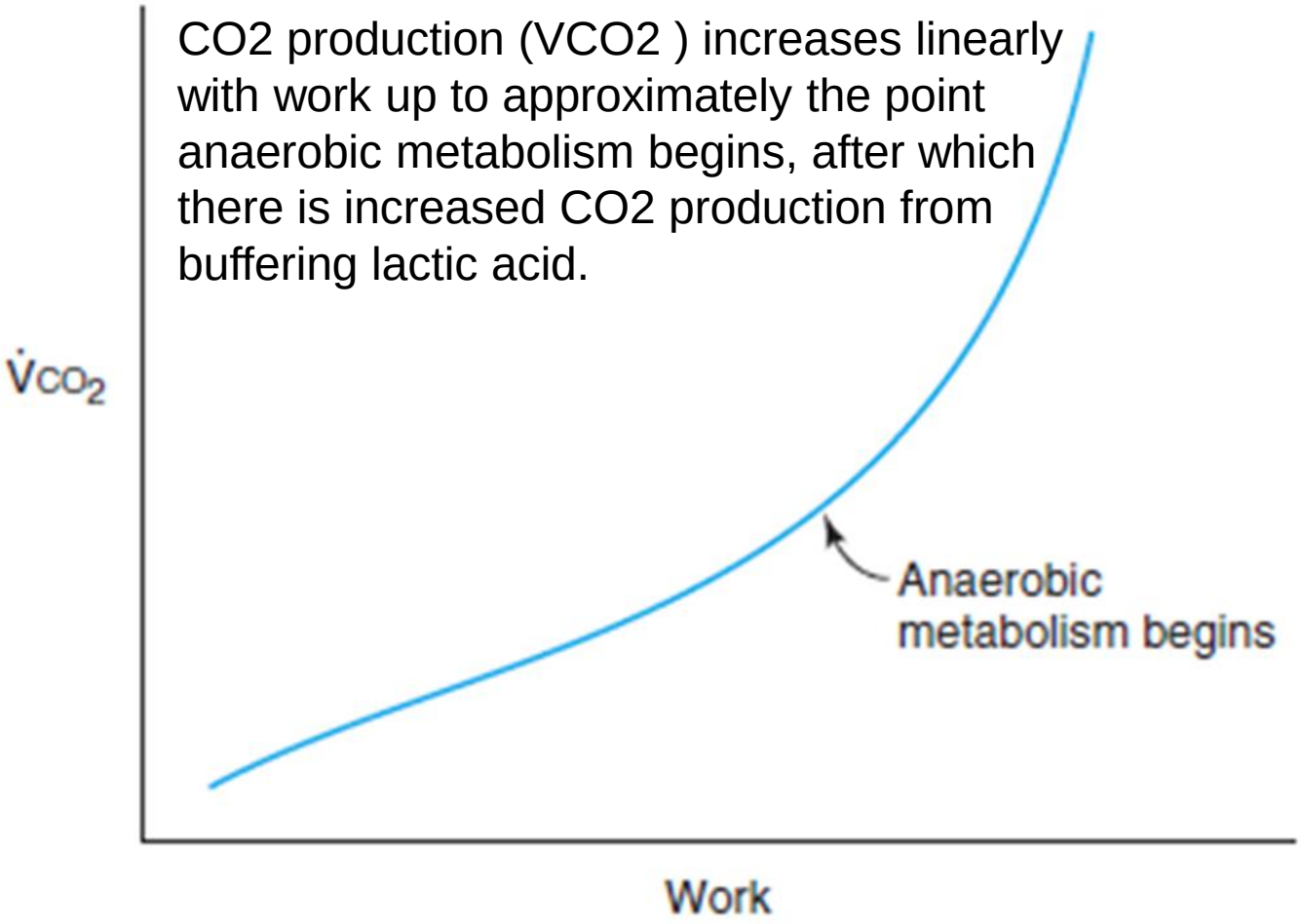
Systolic blood pressure increases 80 to 150 mmHg during exercise in healthy individuals. The diastolic blood pressure generally remains near resting levels.

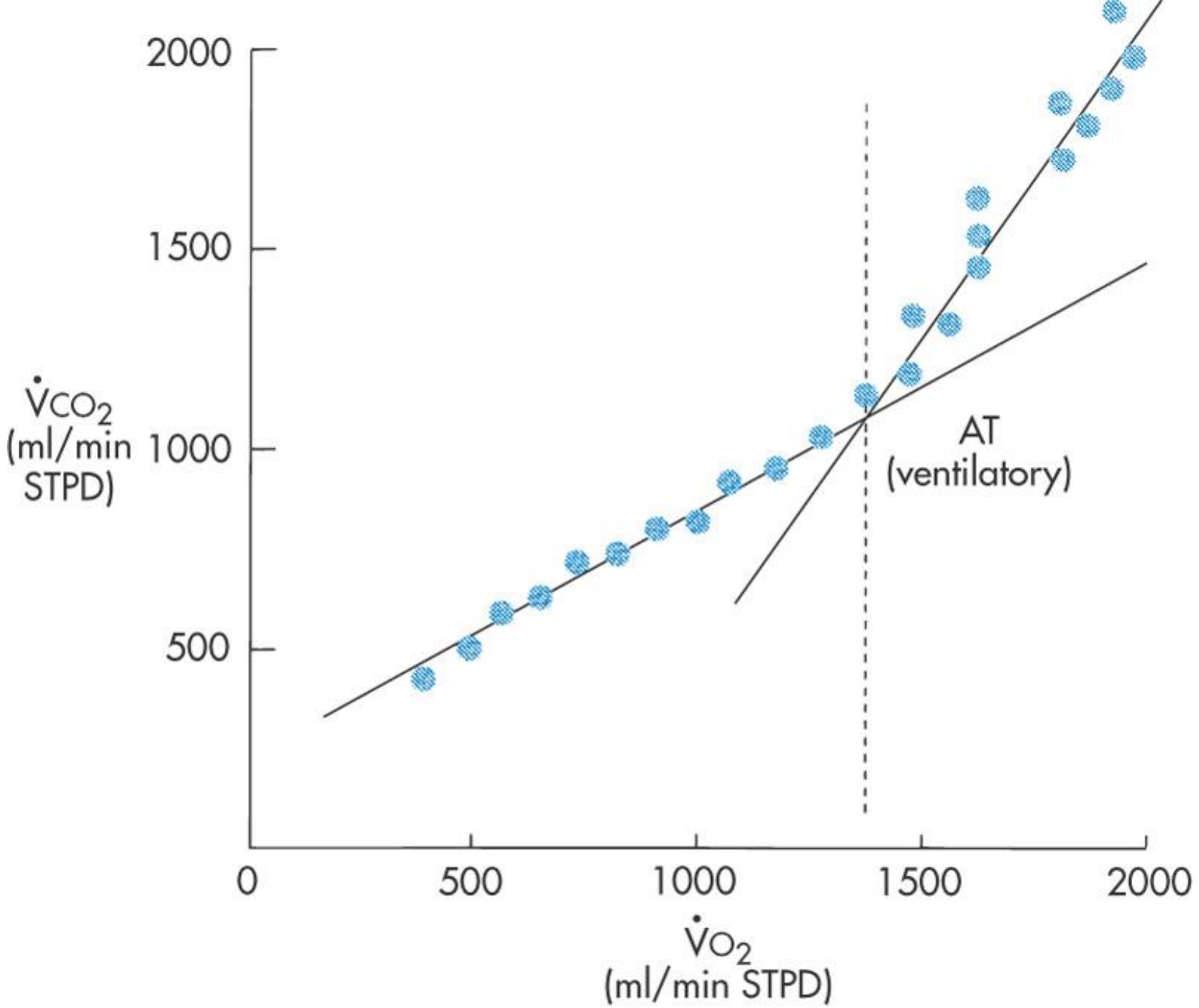
The relationship of heart rate (HR) to oxygen consumption (VO2) is linear with incremental exercise.




Ventilatory ceiling
$\dot{V}_E$
Anaerobic metabolism begins
Work

CO2 production (VCO2) increases linearly with work up to approximately the point anaerobic metabolism begins, after which there is increased CO2 production from buffering lactic acid.





Basic Interpretation

Variable	Normal	Clinical Significance
SaO_2 & PaO_2	≥ 95% 80-100 torr ≤ 4% decrease	**Decreased** in ILD and Pulmonary Vascular Disease **Normal** in heart failure, obesity and deconditioning.
P (A-a) O_2	< 35 mm Hg	**Increased** in COPD, ILD and Pulmonary Vascular Disease. **Normal** in Heart failure & Deconditioned.
VD/VT	< 0.28	**Increased** in Heart Failure, COPD, ILD and Pulmonary Vascular Disease **Normal** in Obesity & Deconditioned.
VE/VCO_2 at AT	< 34	**Increased** in Heart Failure, COPD, ILD and Pulmonary Vascular Disease **Normal** in Obesity & Deconditioned.

Basic Interpretation (Cont)

Variable	Normal	Clinical Significance
VO_2 Max Peak	>84%	**Decreased** in heart failure, COPD, ILD, Pulmonary Vascular Disease, obesity and deconditioning.
AT	> 40% VO_2 Max	**Decreased** in heart failure, COPD, Pulmonary Vascular Disease and deconditioning. **Normal** in Obesity
Heart Rate Heart Rate Reserve	> 90% Max < 15 beats/min.	**Decreased** in COPD, ILD, Pulmonary Vascular Disease, obesity and deconditioning **Normal** in Heart Failure.
Oxygen Pulse	> 80%	**Decreased** in heart failure, COPD, ILD, Pulmonary Vascular Disease and deconditioning. **Normal** in Obesity
VE Max	70-80%	Increased or normal in heart failure, COPD, ILD, Pulmonary Vascular Disease, obesity and deconditioning.

Simplified Interpretation

- Heart Disease
  - Breathing reserve >30%
  - Heart rate reserve <15%
- Pulmonary Disease
  - Breathing reserve > 30%
  - Heart rate reserve >15%

An Adjunct to the CXT--6-Minute Walk Test

- The 6-minute walk test (6MWT) measures the distance a patient can walk on a flat surface in 6 minutes.
- It evaluates response to exertion and is used to determine overall functional capacity or changes in capacity due to therapy in patients with moderate to severe heart or lung disease.
- The 6MWT does not measure O_2 uptake, nor does it help identify either the cause of dyspnea or the factors limiting exercise tolerance.
- If such information is needed, you should recommend a comprehensive *cardiopulmonary exercise test.*

Indications for the 6-Minute Walk Test

Table 3-6 Indications for the 6-Minute Walk Test

Functional Status (Single Measurement)	Pre-/Post-Treatment Comparisons
Chronic obstructive pulmonary disease (COPD)	Lung transplantation
Cystic fibrosis	Lung resection
Heart failure	Lung volume reduction surgery
Peripheral vascular disease	Pulmonary rehabilitation
Fibromyalgia	COPD
Effects of aging	Pulmonary hypertension
	Heart failure

6-Minute Walk Test - Procedure

- Contraindications:
  - Absolute: A recent myocardial infarction (MI) or experienced unstable angina.
  - Relative: A resting heart rate > 120 beats/min; BP > 180/100 mm Hg
- The American Thoracic Society (ATS) standardized protocol (Excerpt)
  - The object of this test is to have the patient walk as far as possible for 6 minutes. The patient will probably get out of breath or become exhausted. The patient is permitted to slow down, stop or r as necessary. able.
  - Equipment: a stopwatch, a movable chair, a recording worksheet, a sphygmomanometer, and a visual Borg Scale to assess the patient's dyspnea and level of exertion. If used, a pulse oximeter m be lightweight and not have to be held by the patient while walking.
- Stop the test if the patient develops chest pain, severe dyspnea, etc.
- Outcomes Measures: Distance, Borg Dyspnea Level, SPO_2
- Interpretation:
  - Most 6MWTs will be done before and after intervention, and the primary question is whether the patient has experienced a clinically significant improvement.
  - Until further research is available, The ATS recommend that's pre/post changes in 6MWD be expressed as an absolute value (e.g., the patient walked 50 m farther).

Take Home Messages

- Cardio Pulmonary Exercises Stress Testing Can be Very Valuable
  - Distinguish among causes of exertional dyspnea
  - Disability determination
  - Screening for Pulmonary Rehabilitation
  - Pre-op evaluation and risk stratification
  - Assess response to therapy
- However, it can be expensive and inconvenient.
- It should be ordered with discretion and adjuncts such as the 6 Min Walk text considered.

Selected Sources & References

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