

CPET - VARIABLES, 9-PANEL DISPLAY, INTERPRETATION, AND LEVEL OF EVIDENCE

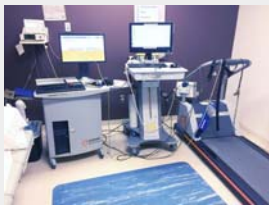
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<https://saliterman.umn.edu/physiology>

Topics

- Indications
- Measured Parameters
- CPET Variables & Special Parameters
- Peak VO_2 , VCO_2 & Ventilatory Threshold
- 9 Panel display
- Interpretation
- Clinical Stratification
- Assessment of CPET Variables
- Suitability of CPET Variables, Class Recommendations & Level of Evidence

Cardiopulmonary Exercise Testing*

*Abbreviated CPET or CPX



Metabolic cart (gas exchange), treadmill and electrocardiogram monitor.



Vyntus® CPX Metabolic Cart and pedal ergometer, showing mask with gas sensors.

Indications for CPET

- Evaluation of dyspnea of unclear etiology after routine cardiopulmonary testing.
- Determination of functional impairment in exercise intolerance.
- Heart failure.
- Evaluation for exercise-induced bronchospasm, and response to therapy.
- Preoperative evaluation prior to lung and/or heart surgery.
- Muscle-metabolic disorders.
- Athlete monitoring.

Table 1: Parameters measured during CPET

- Tidal Volume: VT
- Breathing frequency: Respiratory Rate (RR or f)
- Minute Ventilation: $V_E = VT \times RR$
- Rate of O₂ consumption: O₂ uptake (V_{O_2})
- Maximal V_{O_2} : $V_{O_{2max}}$
- Rate of CO₂ elimination: CO₂ output (V_{CO_2})
- Anaerobic threshold: AT. Also referred to as V_T, Ventilatory Threshold - gases or lactate
- Respiratory Exchange ratio/ Respiratory Quotient (RER/RQ)
- Heart Rate Reserve (HRR)
- HR vs. V_{O_2} slope
- O₂ pulse (V_{O_2}/HR)
- Ventilatory Reserve (VR)
- Maximal ventilation ($V_{E_{max}}$)
- Ventilatory Equivalents for O₂ and CO₂ (V_E/V_{O_2} and V_E/V_{CO_2})
- End-tidal O₂: PETO₂ (partial pressure of end-tidal oxygen)
- End-tidal CO₂: PETCO₂
- Dead space/Tidal volume: V_D/V_T

Detia D, Normandin E, ZuWallack R. Cardiopulmonary exercise testing in the assessment of exertional dyspnea. *Ann Thorac Med*. 2015;10(2):77-86.

Special Parameters...

- MET (metabolic equivalent): The ratio of the *work metabolic rate* to the *resting metabolic rate*. One MET is defined as 1 kcal/kg/hour and is roughly equivalent to the energy cost of sitting quietly.
- MMV (maximum voluntary ventilation): a measure of the *maximum amount of air* that can be inhaled and exhaled within one minute.
- RER (respiratory exchange ratio): The respiratory exchange ratio is the ratio between the amount of *carbon dioxide* produced in metabolism and *oxygen* used. The ratio is determined by *comparing exhaled gases to room air*.

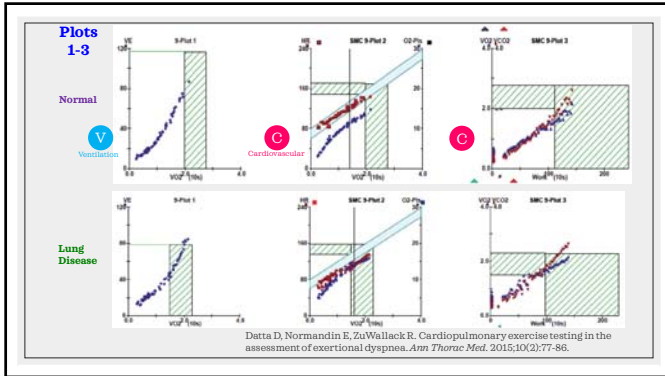
- **VE (minute ventilation):** the *volume* of gas inhaled (inhaled minute volume) or exhaled (exhaled minute volume) from a person's lungs per minute.
- **VE/VO₂ and VE/VCO₂:** These are the *Ventilatory Equivalents* for O₂ and CO₂. They describes the ratio of ventilation (minute volume) to oxygen intake, or to carbon dioxide output.
 - A measure of instantaneous ventilatory and gas exchange efficiency.
 - Tells how many liters does the patient have to breath in order to uptake 1 liter of oxygen or to produce 1 liter of carbon dioxide?

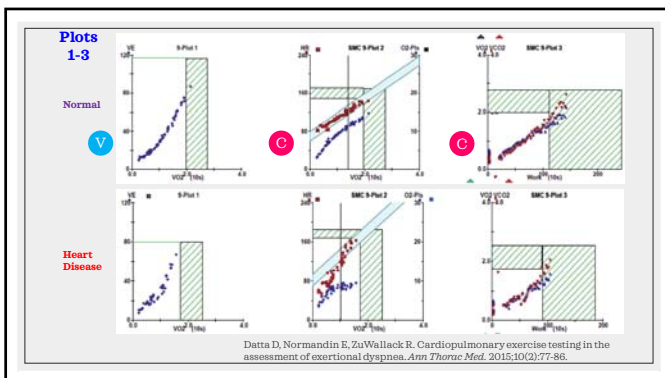
- **AT (Anaerobic Threshold) or VT (Ventilatory Threshold):** refers to the point during exercise at which ventilation starts to increase at a faster rate than VO₂ (volume of oxygen). Two thresholds;
 - **VT1**
 - It is a marker of intensity that can be observed in a person's breathing at a point where lactate begins to accumulate in the blood.
 - As the intensity of the exercise begins to increase, VT1 can be identified at the point where the breathing rate begins to increase.
 - **VT2**
 - At VT2, lactate has quickly accumulated in the blood and the person needs to breathe heavily.
 - At this rapid rate of breathing, the exerciser can no longer speak.

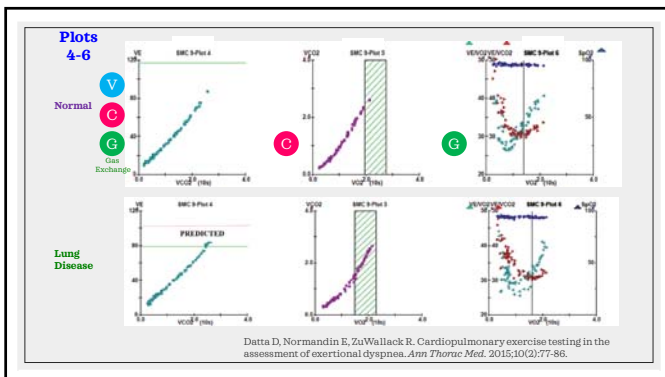
Peak VO₂

- **Global marker of fitness.** It represents the combination of ventricular systolic and diastolic function (cardiac output), vascular function (O₂ delivery), and peripheral skeletal muscle metabolic capacity (O₂ utilization).
- According to the Fick principle, VO₂ is determined by
 - Heart rate, stroke volume, the concentration of hemoglobin and its capacity to transport oxygen.
 - Difference between arterial oxygen saturation (reflecting lung problems and other right-to-left shunts), and
 - Mixed venous oxygen saturation (reflecting peripheral blood flow distribution and oxygen extraction in the muscle).

Wagner J, Agostoni P, Arena R, et al. The Role of Gas Exchange Variables in Cardiopulmonary Exercise Testing for Risk Stratification and Management of Heart Failure with Reduced Ejection Fraction. *Am Heart J* 2018;202:116-126.







VE/VCO₂ (minute ventilation/CO₂ output)...

VE/VCO₂ slope
 Ventilatory volume/carbon dioxide output; reflects ventilatory efficiency
 Normal 25–30
 May be slightly elevated in isolation in otherwise healthy elderly patients
 Elevated value reflects ventilatory inefficiency or ventilation-perfusion mismatch
 Values ≥ 34 indicate clinically significant cardiopulmonary disease (heart failure, pulmonary hypertension, chronic obstructive pulmonary disease)
 Higher values = worse prognosis

Leclerc K. Cardiopulmonary exercise testing: A contemporary and versatile clinical tool. *Cleve Clin J Med.* 2017;84(2):161-168.
 Mezzani A. Cardiopulmonary Exercise Testing: Basics of Methodology and Measurements. *Annals of the American Thoracic Society.* 2017;14(Supplement 1):S3-S11.

Scoring for Heart Failure...

Cardiopulmonary exercise testing scoring system for patients with heart failure

Variable	Value	Points
Ventilation/carbon dioxide (VE/VCO ₂) slope	≥ 34	7
Heart rate recovery*	≤ 6 bpm	5 ^b
Oxygen uptake efficiency slope	≤ 1.4	2
Peak Vo ₂	≤ 14 mL/kg/min	2

Score > 15 points: annual mortality rate 12.2%; relative risk > 9 for transplant, left ventricular assist device, or cardiac death.
 Score < 5 points: annual mortality rate 1.2%.
 *Maximum heart rate minus heart rate at 1 minute in recovery.
^b 2 points if on a beta-blocker.

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Recall: VE/VCO₂ (ventilatory equivalent):
 describes the ratio of ventilation (minute volume) to carbon dioxide output.

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What cardiopulmonary exercise test patterns suggest

Nonspecific: suggest significant cardiopulmonary or metabolic impairment of any sort
 Peak Vo₂ < 80% of predicted
 VE/VCO₂ slope > 34
 Ventilatory (anaerobic) threshold < 40% of peak Vo₂

Deconditioning
 Low-normal peak Vo₂
 Low ventilatory (anaerobic) threshold
 Absence of any other abnormal responses

Obesity
 Increased Vo₂/work slope
 Indexed peak Vo₂ (mL/kg/min) less than predicted
 Absolute Vo₂ (L/min) normal or greater than predicted
 Oxygen indexed to lean body mass normal or greater than predicted

continued...

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Cardiac limitations
 Oxygen pulse (O₂-pulse) < 80% predicted or flattened or falling curve
 Chronotropic incompetence
 Heart rate recovery ≤ 12 beats per minute after 1 minute of recovery
 Standard electrocardiographic criteria for ischemia

Pulmonary limitations
 Peak exercise respiratory rate > 50 per minute
 Ventilatory reserve (peak VE/MVV) < 15%
 Oxygen desaturation by pulse oximetry
 Abnormal results on pretest screening spirometry
 Abnormal exercise flow-volume loops

Muscular disease
 Submaximal cardiac and respiratory responses
 Ventilatory (anaerobic) threshold < 40% of peak Vo₂
 Elevated lactate at any given level of submaximal work

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