

Introduction to Cardiopulmonary Exercise Testing

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Section 2

Glossary of Terms

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The following list contains terms with which you will need to be familiar for the conduct and interpretation of cardiopulmonary exercise tests. A more thorough list of terms is available at the end of the ATS/ACCP statement on cardiopulmonary exercise testing but the list presented here should contain all of the terms you would want to know to interpret cardiopulmonary exercise tests in our laboratory.

- **Carbon Dioxide Output ($\dot{V}CO_2$):** refers to the amount of carbon dioxide exhaled from the body per unit time. It is expressed in ml/min. A normal value at rest is around 200 ml/min. This value increases with progressive exercise. It continues to rise after the completion of exercise as the muscles continue to eliminate carbon dioxide before returning to baseline levels after several minutes. Note that carbon dioxide output can differ from carbon dioxide *production* by the body's metabolic processes but in the steady state production and output are the same.
- **Dead Space Fraction (V_D/V_T):** This is a measure of the physiologic dead space of the lungs and represents the fraction of inspired air that does not exchange gas with capillary blood. It has no units and is expressed as a fraction. It is not part of the standard data output during an exercise test but can be calculated if arterial blood gas values are obtained. In normal individuals, this value is generally between 0.25 and 0.35 and should fall with progressive exercise. A failure to decline or an increase in this value is a marker of either pulmonary vascular disease or interstitial lung disease. The dead space fraction is occasionally reported based on end-tidal CO_2 measurements but these values are poor surrogates for blood gases and should not be used to calculate a dead-space fraction.
- **End-Tidal Partial Pressure of Carbon Dioxide ($P_{ET}CO_2$):** is the PCO_2 of the exhaled gas. It is measured at the end of exhalation and its units are mm Hg. It is taken as a surrogate for alveolar carbon dioxide tensions. This value is typically around 35-40 mm Hg in normals at rest. In normal individuals it will remain at or near this level with progressive exercise until the ventilatory threshold (see below) is reached, at which point it will decrease. Failure to decrease or an increase in this value is a marker of patients with limited ventilatory capacity or neuromuscular impairment.
- **End-Tidal Partial Pressure of Oxygen ($P_{ET}O_2$):** refers to PO_2 of exhaled gas. It is measured at the end of exhalation and its units are mm Hg. It is a surrogate for alveolar oxygen tensions. This value is typically around 100 to 110 mm Hg in normals at rest. In normal individuals it will remain at or near this level with progressive exercise until the ventilatory threshold (see below) is reached, at which point it will increase due to the increase in minute ventilation.

- **Heart Rate Reserve:** refers to the difference between the maximum heart rate reached by the subject at peak exercise and their age-predicted maximum (220-age). A normal heart rate reserve is generally less than 20-30 beats per minute. Because of the wide variability in maximum exercise heart rate among normal subjects, as well as the use of beta-blockers, this is often not a helpful measure.
- **Maximum Voluntary Ventilation (MVV):** refers to the maximal volume of air that can be breathed per minute by the subject. It is measured with a spirometer prior to starting the test. Patients are instructed to take maximal breaths in and out as fast as they can for 12 seconds. The ventilation achieved during this period is multiplied by 5 to give an estimate of the maximal voluntary ventilation. You will compare the subjects' total minute ventilation at peak exercise to this value as part of your efforts to determine the source of the patient's exercise limitation. The $FEV_1 \times 40$ is sometimes used as another estimate of this value.
- **Oxygen Pulse or O_2 Pulse:** refers to the volume of oxygen taken up by the pulmonary blood per heartbeat. It is calculated by dividing the VO_2 by the simultaneously measured heart rate. The units are ml O_2 /beat. The term is derived from the Fick equation and equals the product of stroke volume and the arterial-mixed venous oxygen difference [$C(a-v)O_2$]. If one assumes that $C(a-v)O_2$ reaches a steady state at maximal exercise, then the oxygen pulse can be used as a surrogate measure for stroke volume. The normal value depends on the size of the subject but can range between 8 and 18 ml O_2 /heart beat.
- **Oxygen uptake (VO_2)** refers to how much oxygen the person is taking up and delivering to the tissues per minute. It is measured in ml/min but is often normalized for the subjects weight in kilograms in which case the units are ml/kg/min. At rest, the normal value is about 250 ml/min but in very heavy individuals, you may see higher resting values. **Maximum oxygen uptake ($VO_{2,max}$)** is the amount of oxygen being taken up at peak exercise (i.e. at the point that the person cannot do any more and has to stop exercising). It is measured in the same units as oxygen uptake and is marked by the point at which VO_2 fails to increase further (i.e. plateaus) despite increasing work-rate. If no plateau is identified then the highest VO_2 attained during the test is more properly termed the $VO_{2,peak}$. Clinically, there is little difference between $VO_{2,peak}$ and $VO_{2,max}$. The normal value depends on the age and gender of the subject. Obese individuals have an artifactually low weight normalized $VO_{2,max}$. Therefore, we often report a $VO_{2,max}$ per ideal body weight (eg. ml O_2 /kg of IBW/min)
- **Power:** is work per unit time. In an exercise test, the term refers to the speed and grade of the treadmill or the resistance the individual is pedaling against

on the bicycle. It is measured in watts (W). In most cardiopulmonary exercise tests done in our lab, the subjects are asked to walk/run at steadily increasing speed and grade or pedal against increasing resistance. The rate at which those factors are increased is referred to as the “**ramp**” and it tells us how much the watts will increase per minute during the test. In certain situations, we do constant work-rate tests in which the treadmill speed/grade or bicycle resistance does not change.

- **Respiratory Quotient (R)**: refers to the ratio of carbon dioxide production to oxygen consumption (V_{CO_2}/V_{O_2}). At rest in normal individuals, this value will be around 0.8. It should rise during progressive exercise and will generally exceed values of 1.10 in people who have given a maximum effort. At the conclusion of exercise this value often rises even further (1.3 to 1.4) before falling back to normal because oxygen consumption decreases dramatically once exercise ceases but the muscles continue to offload carbon dioxide.
- **Ventilatory Equivalents for Carbon Dioxide (V_E/V_{CO_2})**: refers to number of liters of ventilation per liter of CO_2 output.. The normal value is typically around 25-30 at the start of exercise and increases once the person reaches their ventilatory threshold. Abnormally high values are a marker of inefficient ventilation, which can be due to hyperventilation or increased dead space. Because V_E and V_{CO_2} both have the same units (L/min), the term V_E/V_{CO_2} has no units. On the exercise data sheet this term will be denoted by “**EqCO₂**”
- **Ventilatory Equivalents for Oxygen (V_E/V_{O_2})**: refers to number of liters of ventilation per liter of oxygen consumed. The normal value is typically around 25-30 and increases once the person reaches their ventilatory threshold. High values are a marker of inefficient ventilation, which can be due to hyperventilation or increased dead-space, a marker of poor gas exchange. For unknown reasons, subjects with heart failure have a high V_E/V_{O_2} . On the exercise data sheet this term will be denoted by “**EqO₂**”
- **Ventilatory Reserve**: also referred to as the “breathing reserve” this term refers to the difference between the maximum minute ventilation reached by the subject at peak exercise and their maximum voluntary ventilation. It is calculated as $V_{E,max}/MVV \times 100$. In some cases, the value of the $FEV_1 \times 40$ is substituted for the maximum voluntary ventilation in this determination. In patients who are not limited by a lung process such as obstructive lung disease, we expect their maximum minute ventilation to be less than 70-80% of their maximum voluntary ventilation or $FEV_1 \times 40$, although highly fit athletes can achieve minute ventilation values at peak exercise that approach or exceed their MVV or $FEV_1 \times 40$.
- **Ventilatory Threshold**: also called “**anaerobic threshold**,” the term refers to the point in a progressive work exercise test where lactic acidosis begins to develop (Our division prefers to use the term ventilatory threshold rather than

anaerobic threshold). This point usually appears at about two-thirds of the way through a good maximal effort. In response to the progressive metabolic acidosis that develops during a normal maximal effort, you will see a compensatory increase in minute ventilation. Identifying whether this threshold is present is a critical part of test interpretation and is discussed in further detail in another section of this syllabus.