Applications of cardiopulmonary exercise testing in cardiac rehabilitation: New insights for a Medical Director

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INTRODUCTION

Cardiopulmonary exercise testing (CPET) has clinical applications to cardiac rehabilitation (CR), including information to assist with the exercise prescription and identifying causes for diminished exercise capacity. Analysis of peak oxygen uptake (VO2) and the identification of the anaerobic threshold (AT) can assist the CR staff to formulate a more precise exercise prescription and enhance the patient's tolerance for activities of daily living. CEPT evaluates exercise intolerance by identifying specific deficiencies within the cardiac, circulatory or pulmonary system that would not be apparent with routine stress testing. A significant proportion of patients referred to CR have no improvement in cardiorespiratory fitness (CRF). Studies have shown that these non-responders may have an associated higher mortality. Greater increases in CRF is independently associated with improved survival. Therefore, efforts are needed to improve CRF and reduce the incidence of non-responders in CR.

LEARNER OBJECTIVES

- Understand the physiologic basis for CEPT interpretation and how it is used to formulate a more precise exercise prescription.
- Understand how the use of CPET in CR can improve prognosis.
- Describe the use of CEPT to diagnose causes of exercise intolerance.

CARDIOPULMONARY EXERICSE TESTING IN CARDIAC REHABILITATION

Metrics from cardiopulmonary exercise testing (CPET) have clinical applications to cardiac rehabilitation (CR), including information to assist with the exercise prescription and identifying causes for diminished exercise capacity. CPET has been shown to be a safe procedure even in populations with underlying high-risk cardiovascular diagnosis.

PEAK OXYGEN UPTAKE (VO2)

The analysis of expired gases provides an indication of oxygen uptake (VO2) quantified in ml/kg per minute (See Figure 1-2). There is a linear relationship between VO2 and work rate (10 ml/min/watt). The VO2max is defined as the point where oxygen uptake can no longer increase despite an increase in workload. This maximal effort is not always feasible in clinical populations. The peak VO2 is the point where an individual stops exercising and therefore is the preferred terminology when grading the oxygen uptake during performance. A Respiratory Exchange Ratio (RER) of >1.15 is an indicator of maximal effort. This is where the expired carbon dioxide (VCO2) exceeds VO2 (VCO2/VO2).

FIGURE 1

FIGURE 2

PHYSIOLOGICAL BASIS FOR CPET TO PRESCRIBE EXERCISE

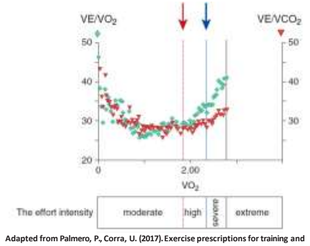
Energy for muscular contraction comes from the production of ATP in the breakdown of substrates (carbohydrate or fatty acids) into pyruvate either by anaerobic glycolysis or more efficiently by aerobic oxidative metabolism in the mitochondria. There is a point with an increased exercise demand where substrates that are broken down to pyruvate to produce ATP do not all go into the oxidative pathway in the mitochondria and some spills over and convert to lactic acid.

Lactic acid is buffered by the bicarbonate system that produces water and CO2. This is called the Lactate Threshold or Anaerobic Threshold (AT). At this point exercise becomes fatiguing and non-sustainable. This is not only important for athletes, but also for patients that wish to do activities of daily living without becoming fatigued. The AT is affected by the same factors that influence peak VO2.

PHYSIOLOGICAL BASIS FOR CPET TO PRESCRIBE EXERCISE

Ventilation (VE) and the CO2 production (VCO2) increase linearly along with VO2 during increasing workloads until the AT is reached. At the AT, the rate of increased CO2 production is greatly accelerated, and hyperventilation is observed. After that point VCO2 and ventilation increases disproportional to VO2. VE can be indexed to VO2 or VCO2 and these values are called ventilatory equivalents. The most sensitive and reliable ventilatory index for the detection of AT is the double criterion (See Figure 3): the systemic increase in the ventilatory equivalent for oxygen (VE/VO2) without a concomitant increased in the ventilatory equivalent for CO2 (VE/VCO2), which remains stable. Later during exercise there is a point where metabolic acidosis starts to develop and ventilation increases disproportional to VCO2 (respiratory compensation point) and the VE/VCO2 relationship increases. This type of information may assist the CR staff in prescribing appropriate training workloads.

FIGURE 3



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CPET AND PROGNOSIS

Low exercise tolerance determined by the AT is not uncommon in patients entering or exiting CR. A significant proportion subjects referred to CR have no improvement in cardiorespiratory fitness (CRF), and studies have shown that these non-responders have a higher mortality. Greater increases in CRF are independently associated with improved survival. Therefore, efforts are needed to improve CRF and reduce the incidence of non-responders.

CPET IN THE DIAGNOSTIC EVALUATION OF EXERCISE INTOLERANCE

Besides being the most accurate test to quantify functional impairment resulting from cardiovascular disease, CEPT is a useful diagnostic test to identify specific deficiencies within the cardiac, circulatory or pulmonary system that would not be apparent with routine stress testing. For example, the relationship of heart rate and VO2 or oxygen pulse can give information regarding stroke volume and cardiac output (e.g. heart failure), a breathing reserve (BR) less than 20-30% would indicate ventilatory impairment (e.g. COPD), and a high VE/VCO2 and VD/VT (dead space ventilation) can indicate abnormal pulmonary gas exchange from areas in the lung that are under-perfused (e.g. chronic pulmonary embolism).

CONCLUSION

CPET is not a standard component of most CR programs. However, CPET may provide important patient information for CR clinicians. The introduction of this quality improvement process to clinical practice requires support from the Medical Directors for CR. Physician in-service training programs is an important first step in this process.

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