Cardiopulmonary Exercise Testing in Cardiac Rehabilitation

Acosta, R.,[1] Mertens, D. J.,[2] Scales, R.[1]

[1]Mayo Clinic, Scottsdale, Arizona, [2]Toronto Rehabilitation Center, Toronto

Abstract

Evidence suggests that cardiovascular (CV) fitness below the 20th percentile for age and gender is associated with increased cardiac death and all-cause mortality. However, studies show that modest improvement in exercise capacity significantly improves survival. Cardiopulmonary exercise testing (CPET) is the most accurate noninvasive quantification of maximal aerobic capacity (i.e. VO_2max or peak VO_2) and the anaerobic threshold (AT). Test results also provide valuable diagnostic and prognostic information for clinicians. Cardiology clinics routinely conduct CPET in patients with unexplained exertional dyspnea and in heart failure patients as a prerequisite to transplantation. CPET in cardiac rehabilitation (CR) appears to be limited to institutions that conduct research. However, the metrics generated from this type of evaluation have clinical applications to CR, including information to assist with the exercise prescription and the identification of post intervention physiological improvement. This review of the CR literature helps clarify the potential role of CPET within clinical practice and the basics of CPET procedures and the interpretation of results are described. The Mayo Clinic experience provides practitioners a guideline for administrative considerations in the clinical application of CPET to CR.

Learning Objectives

- Understand the rationale for CPET in CR.
- Describe the process of CPET administration and interpretation.
- Identify CPET criterion measures of CV fitness and the application to exercise prescription.
- Describe the Mayo Clinic guideline for CPET in CR, including contraindications to testing and alternative options.

Background

Low Exercise Capacity Predicts Cardiac Mortality

Evidence from the Aerobics Center Longitudinal Study (ACLS) and subsequent research suggests that CV fitness below the 20th percentile for age and gender is associated with increased cardiac death and all-cause mortality.[1-4] In a meta-analysis of 33 studies involving 103,000 participants who were followed for an extended period, age-adjusted mortality rates were lowest among the most CV fit individuals and highest among the least fit.[3] In a 6.2 year follow-up of 6,213 US Veteran men, maximal graded exercise testing classified into 5 categorical CV fitness gradients identified that the least fit had >4 times the risk of all-cause mortality compared with those with the highest CV fitness level in both apparently healthy subjects and those with CV disease. The CV fitness level was also a stronger predictor of mortality than the more traditional risk factors, which included smoking, hypertension, high-cholesterol and type 2 diabetes mellitus.[5]

Modest CV Fitness Gains Significantly Improves Survival

In the ACLS, mortality risk ratios from the first to the fifth quintile of fitness were 3.4, 1.4, 1.4, 1.2 and 1.0 respectively. In short, the most sedentary and therefore the least fit had the most to gain from a very modest increase in CV fitness.[1-3]

Background

Toronto Rehabilitation Center CPET Research and Practice

On June 3rd, 1973, the Boston National Enquirer reported that seven heart attack survivors completed the Boston marathon (Figure 1). All of these individuals,[6] and many others to follow,[7] were trained at the world famous Toronto Rehabilitation Center (TRC) under the guidance of Dr. Terry Kavanagh, considered by many, a CR founding father for his pioneering work, which started in the late 1960s. CPET was conducted at intervals (baseline, 12-week, 6, 12 and 18-months) as a standard component of the CR practice to assess the physiological response and prescribe optimal exercise training thresholds for all patients. The TRC model consisted of weekly supervised CR exercise plus independent home exercise and record keeping X 4 days/week (Weeks 1-24) and monthly supervised CR exercise plus the home exercise (Weeks 25-36). Longitudinal prospective CR studies from the TRC show significant reductions in mortality in men and women with improved CV fitness. Individuals who entered the TRC program with low CV fitness measured by CPET gained 1.8 years of survival for each 1 ml/kg per minute of increase in peak VO_2.[8-9]

Mayo Clinic-Rochester CPET Research

Mayo Clinic-Rochester (MCR) has also conducted extensive CPET research over the past 30 years to further our understanding of cardiac populations and influence clinical decisions associated with risk stratification,[10-13] the physiological response[13-20] gender differences[20] and the need for CR and strategic exercise therapy.[21]

CPET Laboratory Procedures

CPET protocols should avoid high incremental stage changes in the exercise workload. A test time of 8-12 minutes is recommended to accurately observe a linear relationship between the workload and the observed metabolic response until the patient can no longer continue to exercise. The treadmill and upright cycle are the most common exercise test modalities and yield the best results; if the patient can walk safely then the treadmill is preferred as long as handrail usage is not excessive (Figure 2). Patients wear a forehead SpO_2 probe and a tightly fitted mask to capture expired gases for breath-by-breath analysis using a metabolic cart (Figure 3). CPET is the most accurate noninvasive quantification of maximal aerobic capacity (i.e. VO_2max or peak VO_2) and the anaerobic threshold (AT). Standard cardio-diagnostic testing procedures are conducted, including blood pressure and continuous 12-lead ECG monitoring (Figure 2). A summary report with the data is generated for ease of interpretation.

CPET Reporting and Interpretation

Metrics from CPET have clinical applications to CR, including information to assist with the exercise prescription and the identification of post intervention physiological improvement.

Maximal effort is not always feasible in clinical populations. Therefore, **peak VO_2 is the preferred terminology over VO_2max when grading the oxygen uptake** during performance. The analysis of expired gases provides an indication of peak VO_2 quantified in ml/kg per minute. A **Respiratory Exchange Ratio (RER)** of >1.15 is an indicator of maximal effort. This is where the expired **carbon dioxide exceeds oxygen uptake (VCO_2/VO_2)**.

The **AT is directly related to the onset of fatigue**, where the body is unable to adequately buffer the excess in lactate concentrations that increase from energy production. The **expired volume (VE)** and the **carbon dioxide production (VCO_2)** increase linearly with increasing workloads until the AT is reached. At the AT, their rate of increase is greatly accelerated and hyperventilation is observed.

The most sensitive and reliable ventilatory index for the detection of AT is the double criterion: the systemic increase in the **ventilatory equivalent for oxygen (VE/VO_2)** without a concomitant increased in the **ventilatory equivalent for carbon dioxide (VE/VCO_2)**. The physiological significance of the increased VE/VO_2 and the decreased VE/VCO_2 at the AT is related to the compensatory mechanisms that buffer the increase in lactic acid. This type of information may assist the CR staff in prescribing appropriate training workloads. Low exercise tolerance determined by the AT is not uncommon in patients entering CR. Exercise training may prolong this point of fatigue onset, which is marker of improved physiological conditioning.

Valuable Diagnostic Information for Clinicians

CPET with expired gas analysis can identify specific deficiencies within the cardiac or pulmonary system that would not be apparent with routine stress testing. For example, in patients with exertional dyspnea, a low AT less than 40% of predicted peak VO_2 is considered pathologically reduced and indicative of circulatory insufficiency. A breathing reserve (BR) less than 20-30% would indicate ventilatory impairment, especially in conjunction with exertional O_2 desaturation. In dyspneic patients with combined cardiac and pulmonary disease, a reduced AT and/or BR may indicate the primary cause of the symptom, with the most dominant reduction explaining the source of the limitation.[22]

Mayo Clinic CPET Administrative Considerations

CPET is conducted in cardio-diagnostics by an exercise physiologist and registered nurse with specialized training and the related required credentials. The test is interpreted by an assigned physician. Specialized equipment includes a metabolic cart for gas analysis, which requires consideration of the expected cost. Another factor is the billing requirement. CPET billing codes for a free standing outpatient clinic are as follows: 93015 (cardiovascular stress testing), 94681 (expired gas analysis) and 94760 (pulse oxygen saturation). Alternate billing codes are used for testing in a hospital setting and further clarification from a billing specialist is recommended.

Mayo Clinic-Rochester CPET Experience

CPET is a standard component of CR at MCR. During the CR new intake visit the nurse determines the patient's eligibility based on their clinical status and established CPET guidelines (see below). A CPET order is proposed for approval by the CR Medical Director.

Non-surgical patients:

- Nurse assesses cath site and patient must be 72 hours post cath
- Conduct symptom limited CPET at program entry and completion, if at least 6 weeks apart. Clinical judgment used for frail/elderly

Surgical patients:

- Conduct symptom limited CPET at program entry, but should be at least 3-weeks post-surgical date using clinical judgment, with a repeat test at program completion (at least 6 weeks apart) to document improvements.

Contraindications:

- Excessive incisional pain
- Severe dyspnea, angina, lightheadedness, syncope.
- Frailty (weakness, unable to exercise on treadmill or cycle ergometer)
- Cognitive impairment
- Sternal dehiscence
- Significant dysrhythmias resulting in symptoms of clinical instability
- Hemodynamic instability: systolic pressure <90 mmHg, resting heart rate > 110 beats/min (non-cardiac transplant)
- Cultural/language barriers
- Patient refusal

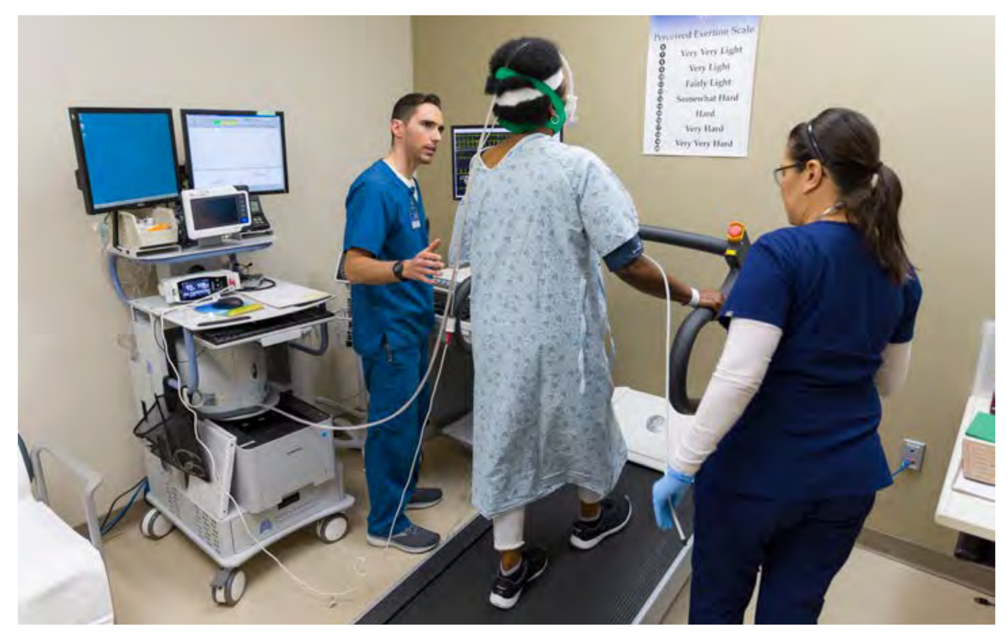
An entry and post program 6-minute walk test is conducted when a CPET is not recommended. The addition of a post program CPET provides the quantification of physiological adaptations and it enables CR staff to customize a strategic exercise prescription for the future.

Figures

Figure 1

Figure 2

Figure 3



Conclusion

CPET is not a standard component of most CR programs. However, CPET may provide important patient information for CR clinicians. Administrative considerations required in the application of CPET to CR include the introduction of department specific quality improvement processes, staff training, specialized equipment and billing support.

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