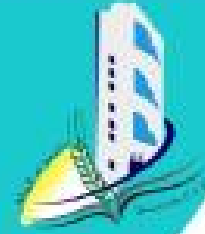




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معهد علوم وتقنيات النشاطات البدنية والرياضية



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Cardiopulmonary exercise testing : an overview

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Abstract:

Cardiopulmonary exercise testing (CPET) is an objective assessment of functional capacity. It has become increasingly popular in clinical, research, and athletic performance settings.

One of the most valuable applications of clinical exercise testing is the ability to distinguish cardiovascular from pulmonary causes of exercise limitation. In addition, CPET is underutilized in Algerian hospitals and medical centers due to the limited availability of CPEX equipment and the personnel skilled in its application.

ملخص

اختبار الجهد البدني مع قياس الوظائف القلبية التنفسية هو تقييم موضوعي للقدرة الوظيفية. فقد أصبح شائعاً ويستخدم بنطاق واسع في المجال الإكلينيكي ، مجال البحث العلمى و الأداء الرياضى.

يعتبر اختبار الجهد البدني مع قياس الوظائف القلبية التنفسية كإجراء إكلينيكي مهم خصوصاً وذلك لقدرته على تمييز القصور القلبي الوعائى من القصور الرئوي كأسباب للحد من الجهد البدني.

وبالإضافة إلى ذلك ، لا يُستخدم هذا الإختبار في المستشفيات والمراكز الطبية الجزائرية استخداماً كافياً بسبب محدودية المعدات و الأجهزة والمتمرسين المهرة في تطبيقاته.

Introduction:

By using gas exchange analysis, cardiopulmonary exercise testing testing allows for the simultaneous study of cellular, cardiovascular, and ventilatory responses to exercise. As illustrated in **Fig.1** (Chase & Bensimhon, 2007)

Cardiopulmonary exercise testing (CPEX or CPET) offers a superior evaluation of a patient's integrated cardiovascular, respiratory and metabolic response to exercise by combining the standard measures of electrocardiography (ECG), blood pressure, O₂ saturation and exercise workload with ventilatory gas exchange data (McGregor & Ingle, 2014).

CPET is increasingly being used in a wide spectrum of clinical applications for the evaluation of undiagnosed exercise intolerance and for the objective determination of functional capacity and impairment. Its use in patient management is increasing with the understanding that resting pulmonary and cardiac function testing cannot reliably predict exercise performance and functional capacity and that overall health status correlates better with exercise tolerance than with resting measurements(Albouaini et al., 2007).

Clinical indications for CPET:

The CPET is used largely in clinical purposes and in evaluation. Indications for clinical exercise testing encompass three general categories: (a) diagnosis (e.g., presence of disease or abnormal physiologic response), (b) prognosis (e.g., risk for an adverse event), and (c) evaluation of the physiologic response to exercise (e.g., blood pressure [BP] and peak exercise capacity). The most common diagnostic indication is the assessment of symptoms suggestive of IHD (Medicine, 2018).

There are a number of specific indications for CPET;

1. Evaluation of exercise tolerance
2. Evaluation of undiagnosed exercise intolerance
3. Evaluation of patients with cardiovascular diseases
4. Evaluation of patients with respiratory diseases/symptoms
5. Preoperative evaluation
6. Exercise evaluation and prescription for pulmonary rehabilitation
7. Evaluation of impairment/disability
8. Evaluation for lung, heart, and heart–lung transplantation (“ATS/ACCP Statement on Cardiopulmonary Exercise Testing,” 2003).

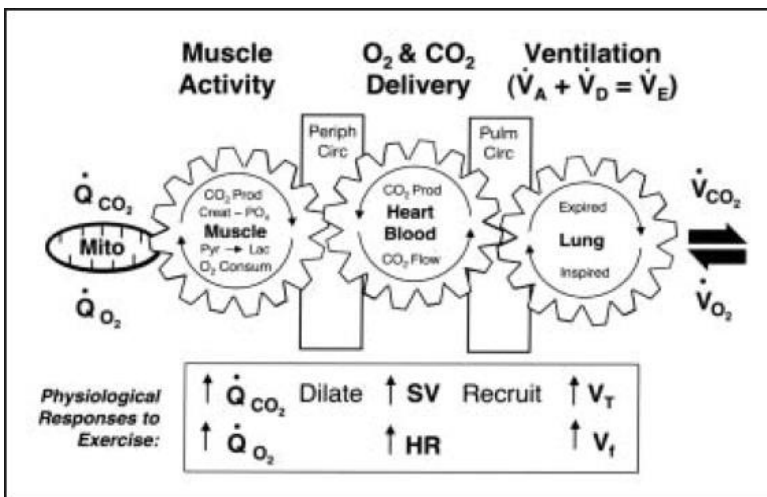


Figure 1. Gas transport mechanisms coupling cellular (internal) respiration to pulmonary (external) respiration (Milani et al., 2006).

Cardiopulmonary Exercise-Testing Equipment:

Two modes of exercise are commonly employed in cardiopulmonary exercise tests: treadmill and cycle ergometer (Table 1)

	Cycle	Treadmill
VO ₂ max	lower	higher
Work rate measurement	yes	no
Blood gas collection	easier	More difficult
Noise and artefacts	less	more
Safety	safer	Less safe ?
Weight bearing in obese	less	more
Degree of leg muscle training	less	more
More appopriate for:	patients	Active normal subject

Table 1: exercise equipment; cycle ergometry and treadmill (“ATS/ACCP Statement on Cardiopulmonary Exercise Testing,” 2003).

Most clinical systems rely on breath-by-breath analysis techniques because they provide the best measures of the metabolic response to exercise. A non-rebreathing valve is connected to a mouthpiece to prevent mixing of inspired and expired air. Oxygen and carbon dioxide gas analysers are usually incorporated in a “metabolic cart” designed specifically for functional testing. Respiratory volumes are computed by integrating the air flow signals over the time of inspiration and expiration. Average minute volumes are derived from the breath-by-breath data multiplied by the respiratory rate (Albouaini et al., 2007).

For complete testing, the CPX cart should also be able to perform resting spirometry to measure FEV1 and FVC, although it need not be able to measure lung volumes or diffusion capacity. With the expired gas data in hand, the metabolic cart is then able to use algorithms to back calculate values for inspired CO₂ and O₂ and display these in tabular format along with values for ventilation (V_e) or the amount of air being moved over a given time. Although most of the hands-on CR

staff can be trained to operate a metabolic cart and run an uncomplicated CPX test, there are many nuances to testing and numerous sources for potential error. Thus, we strongly advocate that CPX testing be done by an exercise physiologist who has been well trained in the modality and can troubleshoot the cart and make adjustments quickly (Chase & Bensimhon, 2007).

Physiology of exercise testing :

Aerobic exercise represents a balance between the cardiovascular and respiratory systems' ability to supply oxygen in exchange for carbon dioxide to meet the metabolic needs of working muscles and organs. This complex process can be simplified into four categories:

- Pulmonary ventilation: the movement of oxygenated air into and deoxygenated air out of the lungs.
- Pulmonary diffusion: the exchange of oxygen and carbon dioxide between the alveoli and capillaries of the lungs.
- Transportation of oxygenated blood to the muscles and organs.
- Capillary diffusion: the exchange of oxygen and carbon dioxide between capillaries and muscle.

During exercise, the respiratory and cardiovascular systems must augment ventilation, diffusion, and transportation to meet the metabolic demands of increased workloads (Gentile, 2019).

In exercise testing, the physiological path of oxygen from atmosphere to muscle and the return journey through carbon dioxide can be assessed. This journey involves the oxygen cascade through respiratory, cardiovascular and peripheral vascular systems to skeletal muscle. When considering oxygen, oxygen uptake (VO_2 in ml/min) can be shown as:

$$*VO_2 = (SV \times HR) \times (CaO_2 - CvO_2) \text{ during exercise.}$$

* $VO_{2max} = (SV_{max} \times HR_{max}) \times (CaO_{2max} \times CvO_{2max})$ at maximal exercise
 where SV is stroke volume, HR is heart rate, CaO₂ is arterial oxygen content and CvO₂ is central venous oxygen content. During increasing resistance exercise, the body will increase oxygen delivery to its maximal ability in an attempt to maintain efficient energy production. This can be seen by an increase in minute volume ventilation and cardiac output as a consequence of increasing metabolic requirements (Burnside & Snowden, 2017).

Derived variables
Peak oxygen consumption per unit time
Breathing reserve*
Oxygen saturation
Anaerobic threshold
Respiratory exchange ratio
Oxygen pulse
Ventilatory equivalent for carbon dioxide
Peak oxygen consumption per unit time adjusted for lean body mass*
Oxygen pulse adjusted for lean body mass*

Table 2. Metabolic Parameters Derived From Cardiopulmonary Stress Testing (McGregor, G., & Ingle, L. (2014)

Criteria for terminating the exercise test :

In the vast majority of cardiopulmonary exercise tests, patients should be verbally encouraged before and during the test, to give a maximal effort with the goal of achieving physiologic limitation. In particular, it should be stressed that exceeding a preset heart rate criterion is not a useful criterion for stopping exercise. The most

accepted criteria for exercise termination before symptom limitation are listed in Table 3("ATS/ACCP Statement on Cardiopulmonary Exercise Testing," 2003).

Criteria for terminating the cpet.
Chest pain suggestive of ischemia
Ischemic ECG changes
Complex ectopy
Second or third degree heart block
Fall in systolic pressure >20 mm Hg from the highest value during the test
Hypertension (>250 mm Hg systolic; >120 mm Hg diastolic)
Severe desaturation: SpO ₂ ≤ 80% when accompanied by symptoms and signs of severe hypoxemia
Sudden pallor
Loss of coordination
Mental confusion
Dizziness or faintness
Signs of respiratory failure

Table3: indications for exercise termination("ATS/ACCP Statement on Cardiopulmonary Exercise Testing," 2003).

Conclusion :

CPET remains the gold standard for assessing the functional capacity that reflects the entire oxygen transport system. Measurement of exercise gas exchange provides objective and reproducible indices of functional capacity, giving important informations and the the ability to unmask pathology which is otherwise occult when investigated at rest. CPET is underutilized in Algerian

hospitals and medical centers. Much greater efforts are needed to raise the awareness among physicians on the usefulness of CPET.

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