EXERCISE TESTING IN ASSESSMENT AND MANAGEMENT OF PATIENTS IN CLINICAL PRACTICE - PRESENT SITUATION

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OBJECTIVE

1) To review recent scientific advances in exercise testing methods and results that is important for a clinical practioner.
2) To understand the utility and limitations of different methods of exercise testing.
3) To understand appropriate method in assessment and management of patients.
4) To appreciate that exercise testing results can have greater clinical meaning when interpreted in context of relevant patient information.
5) To understand that additional study is required to further characterize both current and future roles of exercise testing in clinical medicine.

INTRODUCTION

The need of the hour is to understand the different methods used worldwide to asses the patients exercise performance and response in clinical practice.

Clinical Exercise Testing (CET) is increasingly gaining importance in clinical medicine, by helping the clinician to objectively evaluate the physiological functions. The result helps to predict the outcome and mortality in different clinical circumstances.

COMMON METHODS TO ASSES EXERCISE RESPONSE AND PERFORMANCES IN CLINICAL PRACTICE

Simple test are easily performed but limits physiological understanding.

More comprehensively performed tests may provide detail information and understanding but is costly and demanding. The clinician has to choose the type of test to perform for a particular patient.

Commonly the following test is performed worldwide:

1) 6 min walk test
2) Shuttle Walk Test
3) Exercise Induced Bronchoconstriction Test
4) Cardiac Stress Test
5) Clinical Exercise Test (CET)

6 MINUTE WALK TEST

It is a safe simple and practical test of sub maximal functional capacity, which measures the maximum distance walked by a subject in 6 minutes. Advantage of this test is that it provides an acceptable index of functional disability and correlates with oxygen uptake measured during comprehensive testing. This test gives very limited information regarding physiological contributors to activity related symptoms or about mechanism of exercise limitation. Currently this test is used in lung transplantation, lung volume reduction surgery, pulmonary rehabilitation and in predicting mortality in cardiac patients and patients with pulmonary vascular disorders.

SHUTTLE WALK TEST

It measures the distance walked by a patient in a 10 meter course, being paced by an audio signals from a cassette. The intensity of exercise reached is comparable to test performed on a treadmill, as the walking speed is progressively increased until the patient reaches exhaustion. Modification of maximal SWT for determination of endurance performance – similar to maximal and constant (sub maximal) cycle ergometry may be done.

EXERCISE INDUCED BRONCHOCONSTRICTION

In this physical activity triggers acute airway narrowing in patients with heightened airway responsiveness. In susceptible patients EIB typically occurs 5to 10 minutes
after exercise and generally resolves in 20 to 30 minutes. In some clinical situation where bronchial challenge is unavailable or not diagnostic EIB should be undertaken.

Common protocols to be followed include exercise on treadmill or cycle ergometry at a workload of 60% to 80% of predicted maximum or the intensity that will elicit a heart rate of 80% of predicted maximum for 6 to 8 minutes. The goal is to produce ventilation equal to those attained during activity to produce symptom of EIB.

15% percent decrease in FEV₁ following exercise is diagnostic of EIB. And 10-15% decrease in FEV₁ would be suggestive of EIB.

CARDIAC STRESS TEST

Common type of exercise testing, the primary purpose of which is diagnosis and management of myocardial infarction. Bruce protocol is commonly used and the single most reliable indication of ischemia is ST segment depression. During this test ECG and BP is measured, but the utility may be enhanced by concurrent measurement of ventilator parameters and respiratory gas exchange.

CLINICAL EXERCISE TESTING (CET)

CET involves the measurement of respiratory gas exchange i.e. oxygen uptake, carbon dioxide, minute ventilation, other variables while monitoring ECG, blood pressure, pulse oximetry and exertion perceived (Borg Scale) during a maximal symptom limited incremental test on a cycle ergometer or treadmill. Simultaneous measurement of blood gasses and spirometry provides with more detail information on gas exchange and ventilation. CET provides a global assessment of integrative exercise responses which are not adequately reflected by measurement of individual organ system function on rest. Peak oxygen uptake remains the gold standard for exercise capacity.

It has traditionally been undertaken with an incremental stepwise or ramp control protocol to exhaustion. In patients of COPD, acute response to an inhaled bronchodilator was assessed using various exercise tests. The authors found endurance time with a constant – workload exercise (80% of maximal work rate) was the most responsive end point to the effect of bronchodilator showing 19% improvement in exercise duration time. Arterial blood gasses measured at 5 minute constant – work exercise testing may give practical and cost effective alternative when arterial oxygen saturation, PaO₂, alveolar – arterial oxygen pressure difference and ratio of physiological dead space to tidal volume are required.

INDICATIONS FOR EXERCISE TESTING IN CLINICAL PRACTICE

1. Evaluation of Exercise Intolerance
2. Evaluation of Unexplained exertional Dyspnea
3. Evaluation of patients of cardiovascular diseases
4. Evaluation of Patients of respiratory diseases
   - COPD
   - ILD
   - Pulmonary Vascular Diseases
   - Cystic Fibrosis
5. Preoperative evaluation
6. Evaluation for transplantation and Lung Volume Reduction Surgeries
7. Pulmonary Rehabilitation
8. Impairment disability

Table 1 to 11 illustrates the indication, contraindication and guidelines laid down by various international authorities for cardio pulmonary exercise testing in clinical setting.

CONCLUSION

Cardiopulmonary exercise test is a helpful tool for evaluation of the disease and management in clinical practice and rapidly evolving in one of the important investigative and diagnostic test. There are different methods used in various clinical setting. The clinical exercise testing a simple and easy to perform test for a pulmonologist as compared to the other conducted tests and relatively more simpler and cost effective test, which needs to be more frequently used in our day to day clinical practice in relevant patients.

Table 1: Overview of Cardiopulmonary Exercise Testing

| Clinical Status Evaluation |
|----------------------------|
| Clinical diagnosis and reason(s) for CPET |
| Health questionnaire (cardiopulmonary); physical activity profile |
| Medical and occupational history and physical examination |
| PFTs, CXR, ECG, and other appropriate laboratory tests |
| Determination of indications and contraindications for CPET |

| Pretest Procedures |
|--------------------|
| Abstain from smoking for at least 8 h before the test |
| Refrain from exercise on the day of the test |
| Medications as instructed |
| Consent form |

| Conduct of CPET |
|-----------------|
| Laboratory procedures |
| Quality control |
| Equipment calibration |
| Protocol Selection |
| Incremental versus constant work rate; invasive versus noninvasive |
| Patient preparation |
| Familiarization |
| 12-lead ECG, pulse oximetry, blood pressure |
| Arterial line (if warranted) |
| Cardiopulmonary exercise testing |
Interpretation of CPET Results

Data processing
Quality and consistency of results
Comparison of results with appropriate reference values
Integrative approach to interpretation CPET results
Preparation of CPET report

Definition of abbreviations: CPET = Cardiopulmonary exercise testing; CXR = chest X-ray; ECG = electrocardiogram; PFTs = pulmonary function tests.

Table II: Indications for Cardiopulmonary Exercise Testing

Evaluation of exercise tolerance
- Determination of functional impairment or capacity (peak \( V_{O2} \))
- Determination of exercise-limiting factors and pathophysiologic mechanisms.

Evaluation of undiagnosed exercise intolerance
- Assessing contribution of cardiac and pulmonary etiology in coexisting disease.
- Symptoms disproportionate to resting pulmonary and cardiac tests.
- Unexplained dyspnea when initial cardiopulmonary testing is nondiagnostic.

Evaluation of patients with cardiovascular disease
- Functional evaluation and prognosis in patients with heart failure
- Selection for cardiac transplantation
- Exercise prescription and monitoring response to exercise training for cardiac rehabilitation.
  (special circumstance; i.e. pacemakers)

Evaluation of patients with respiratory disease
- Functional impairment assessment (see specific clinical applications)
- Chronic obstructive pulmonary disease
  Establishing exercise limitation(s) and assessing other potential contributing factors, especially occult heart disease (ischemia)
  Determination of magnitude of hypoxemia and for \( O_2 \) prescription
  When objective determination of therapeutic intervention is necessary and not adequately addressed by standard pulmonary function testing.
- Interstitial lung diseases
  Detection of early (occult) gas exchange abnormalities
  Overall assessment/monitoring of pulmonary gas exchange
  Determination of magnitude of hypoxemia and for \( O_2 \) prescription
  Determination of potential exercise-limiting factors
  Documentation of therapeutic response to potentially toxic therapy
- Pulmonary vascular disease (careful risk-benefit analysis required)
- Cystic fibrosis
- Exercise-induced bronchospasm

Specific clinical applications
- Preoperative evaluation
- Lung resectional surgery
- Elderly patients undergoing major abdominal surgery
- Lung volume resectional surgery for emphysema (currently investigational)
- Exercise evaluation and prescription for pulmonary rehabilitation
- Evaluation for impairment–disability
- Evaluation for lung, heart–lung transplantation

Definition of abbreviations: \( V_{O2} = \text{oxygen consumption} \)

Reference 20

Table III: Absolute and Relative Contraindications for Cardiopulmonary Exercise Test

| Absolute | Relative |
|----------|---------|
| Acute myocardial infarction (3-5 days) | Left main coronary stenosis or its equivalent |
| Unstable angina | Moderate stenotic valvular heart disease |
| Uncontrolled arrhythmias causing symptoms or hemodynamic compromise | Severe untreated arterial hypertension at rest (> 200 mm Hg systolic, > 120 mm Hg diastolic) |
| Syncope | Tachyarrhythmias or bradyarrhythmias |
| Active endocarditis | High-degree atrioventricular block |
| Acute myocarditis or pericarditis | Hypertrophic cardiomyopathy |
| Symptomatic severe aortic stenosis | Significant pulmonary hypertension |
| Uncontrolled heart failure | Advanced or complicated pregnancy |
| Uncontrolled pulmonary embolus or pulmonary infarction | Electrolyte abnormalities |
| Thrombosis of lower extremities | Orthopedic impairment that compromises exercise performance |
| Suspected dissecting aneurysm | |
| Uncontrolled asthma | |
| Pulmonary edema | |
| Room air desaturation at rest < 85%* | |
| Respiratory failure | |
| Acute noncardiopulmonary disorder that may affect exercise performance or be aggravated by exercise (i.e. infection, renal failure, thyrotoxicosis) | |
| Mental impairment leading to inability to cooperate | |

References 21, 22 and 23.

* Exercise patient with supplemental \( O_2 \).
Table IV: Indications for Exercise Termination

| Indications                              |
|------------------------------------------|
| 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: \( \text{SpO}_2 < 80\% \) when accompanied by symptoms and signs of severe hypoxemia |
| Sudden pallor                            |
| Loss of coordination                     |
| Mental confusion                         |
| Dizziness or faintness                    |
| Signs of respiratory failure             |

Definition of abbreviations: ECG = electrocardiogram; \( \text{SpO}_2 \) = arterial oxygen saturation as indicated by pulse oximetry.
References 22, 24, 25 and 26.

Table V: Usual Cardiopulmonary Exercise Response Patterns

| Measurement                        | Heart Failure | COPD | ILD | Pulmonary Vascular Disease | Obesity | Deconditioned |
|-----------------------------------|---------------|------|-----|-----------------------------|---------|---------------|
| \( \text{VO}_2\text{max or VO}_2\text{peak} \) | Decreased     | Decreased | Decreased | Decreased | Decreased for actual, normal for ideal weight | Decreased |
| Anaerobic threshold               | Decreased     | Normal/decreased | Normal or decreased | Normal | Normal | Normal or decreased |
| Peak HR                           | Variable, usually normal in mild | Decreased, normal in mild | Decreased | Normal/slightly decreased | Normal/slightly decreased | Normal/slightly decreased |
| \( \text{O}_2 \text{ pulse} \)        | Decreased     | Normal or decreased | Normal or increased | Normal | Normal or increased | Normal |
| \( (\text{Ve}/\text{MVV}) \times 100 \) | Normal or decreased | Increased | Increased | Increased | Normal | Normal |
| \( \text{Ve}/\text{Vco}_2 \) (at AT)   | Increased     | Increased | Increased | Increased | Normal | Normal |
| \( \text{Vd}/\text{Vt} \)            | Increased     | Increased | Decreased | Increased | Normal | Normal |
| \( \text{PaO}_2 \)                  | Normal        | Variable | Decreased | Decreased | Normal | May decrease |
| \( \text{P}(\text{A-a})\text{O}_2 \)   | Usually normal | Varied, usually increased | Increased | Increased | May decrease | Normal |

Definition of abbreviations: AT = anaerobic threshold; COPD = chronic obstructive pulmonary disease; HR = heart rate; ILD = interstitial disease; MVV = maximal voluntary ventilation; \( \text{P}(\text{A-a})\text{O}_2 \) = alveolar-arterial difference for oxygen pressure; \( \text{Vi}/\text{Vt} \) = ratio of physiologic dead space to tidal volume; Ve = minute ventilation; \( \text{Vco}_2 \) = carbon dioxide output; \( \text{Vo}_2\text{max} \) = maximal oxygen uptake; \( \text{Vo}_2\text{peak} \) = peak oxygen uptake.
References 37, 38 and 28

* Decreased, normal, and increased are with respect to the normal response.

Table VI: Measurements during Cardiopulmonary Exercise Testing

| Measurements                        | Nominvasive                     | Invasive (ABGs)     |
|-------------------------------------|---------------------------------|---------------------|
| External work                       | WR                              | Lactate             |
| Metabolic gas exchange              | \( \text{VCO}_2, \text{Vo}_2\text{, RER, AT} \) |                     |
| Cardiovascular                      | \( \text{HR, ECG, BP, O}_2\text{ pulse} \) |                     |
| Ventilatory                         | \( \text{Va, Vr, Fr} \)         |                     |
| Pulmonary gas exchange              | \( \text{SpO}_2, \text{Ve}/\text{Vco}_2, \text{Vr}/\text{Vo}_2, \text{PetO}_2, \text{PetCO}_2 \) | \( \text{Pao}_2, \text{Sao}_2, \text{P}(\text{A-a})\text{O}_2, \text{Vi}/\text{Vt} \) |
| Acid-base                           |                                  | \( \text{pH, Paco}_2, \text{standard HCO}_3 \) |
| Symptoms                            | Dyspnea, fatigue, chest pain    |                     |

Definition of abbreviations: ABGs = Arterial blood gases; AT = anaerobic threshold; BP = Blood pressure; ECG = electrocardiogram; Fr = respiratory frequency; HR = heart rate; \( \text{P}(\text{A-a})\text{O}_2 \) = alveolar-arterial difference for oxygen pressure; \( \text{Paco}_2 \) = arterial carbon dioxide pressure; \( \text{PaO}_2 \) = arterial oxygen pressure; \( \text{PETCO}_2 \) = end-tidal \( \text{PCO}_2 \); \( \text{PETO}_2 \) = end-tidal \( \text{PO}_2 \); RER = respiratory exchange ratio; \( \text{Sao}_2 \) = arterial oxygen saturation; \( \text{SpO}_2 \) = arterial oxygen saturation as indicated by pulse oximetry; \( \text{Vco}_2 \) = carbon dioxide output; \( \text{Ve} \) = minute ventilation; \( \text{Vi}/\text{Vt} \) = ratio of physiologic dead space to tidal volume; \( \text{Vo}_2 \) = oxygen uptake; \( \text{Vt} \) = tidal volume; WR = work rate. 31
Table VII: Suggested normal guidelines for interpretation of Cardiopulmonary Exercise Testing

| Variables                      | Criteria of Normality                      |
|--------------------------------|--------------------------------------------|
| Vo₂max or Vo₂ peak            | > 84% predicted                            |
| Anaerobic threshold           | > 40% Vo₂max predicted; wide range of normal (40-80%) |
| Heart rate (HR)               | HRmax > 90% age predicted                  |
| Heart rate reserve (HRR)      | HRR < 15 beats/min                         |
| Blood pressure                | < 220/90                                   |
| O₂ pulse (Vo₂/HR)             | > 80%                                      |
| Ventilatory reserve (VR)      | MVV - Vemax: > 11 or Vemax/MVV x 100 : < 85%, Wide normal range: 72 + 15% |
| Respiratory frequency (fr)    | < 60 breaths/min                           |
| Ve/ Vco₂ (at AT)              | < 34                                       |
| Vd/Vt                         | < 0.28; < 0.30 for age > 40 years          |
| Pao₂                          | > 80 mm Hg                                 |
| P (a-a) O₂                    | < 35 mm Hg                                 |

References 27, 28, 30, 35, 22 and 32

* Maximum or peak cardiopulmonary responses except for anaerobic threshold and Ve/Vco₂ at AT.

Table VIII: Integrative approach to the interpretation of Cardiopulmonary exercise testing results

1. Determine reason(s) for CPET
2. Review pertinent clinical and laboratory information (clinical status)
3. Note overall quality of test, assessment of subject effort, and reasons for exercise cessation
4. Identify key variables: initially Vo₂, and then HR, VE, Sao₂, and other measurements subsequently.
5. Use tabular and graphic presentation of the data
6. Pay attention to trending phenomena : submaximal through maximal responses.
7. Compare exercise responses with appropriate reference values.
8. Evaluate exercise limitation : physiologic versus nonphysiologic.
9. Establish patterns of exercise responses.
10. Consider what conditions / clinical entities may be associated with these patterns.
11. Correlae CPET results with clinical status.
12. Generate CPET report.

Definition of abbreviations : CPET = cardiopulmonary exercise testing; HR = heart rate; Sao₂ = arterial oxygen saturation; Ve = minute ventilation; Vo₂ = oxygen uptake.

Table IX: Cardiopulmonary Exercise Response Patterns

| Measurement                  | Heart Failure | COPD | ILD | Vascular Disease | Obesity | Deconditioned |
|------------------------------|---------------|------|-----|------------------|---------|---------------|
| Vo₂max or Vo₂ peak          | Decreased     | Decreased | Decreased | Decreased | Decreased | Decreased |
| Anaerobic threshold         | Decreased     | Normal/ decreased | Normal or decreased | Decreased | Normal | Normal or decreased |
| Peak HR                     | Variable, usually normal in mild | Decreased, normal in mild | Decreased | Normal/slightly decreased | Normal/slightly decreased | Normal/slightly decreased |
| O₂ pulse                    | Decreased     | Normal or decreased | Normal or increased | Normal | Normal or increased | Normal |
| (Ve/MVV) x 100              | Normal or decreased | Increased | Increased | Increased | Normal | Normal |
| Ve/Vco₂ (at AT)             | Increased     | Increased | Increased | Increased | Normal | Normal |
| Vd/Vt                       | Increased     | Increased | Increased | Normal | Normal | Normal |
| Pao₂                        | Normal        | Variable | Decreased | Normal/ may increase | Normal | Normal |
| P(Δ-a)O₂                    | Usually normal | Variably, usually increased | Increased | Increased | May decrease | Normal |

* Decreased, normal, and increased are with respect to the normal response.

Definition of abbreviations : AT = anaerobic threshold; COPD = chronic obstructive pulmonary disease; HR = heart rate; ILD = interstitial disease; MVV = maximal voluntary ventilation; P(Δ-a)O₂ = alveolar-arterial difference for oxygen pressure; Ve/Vt = ratio of physiologic dead space to tidal volume; Ve = minute ventilation; Vco₂ = carbon dioxide output; Vo₂ max = maximal oxygen uptake; Vo₂ peak = peak oxygen uptake.

References 37, 36, 28
Table XI: Selected reference values for maximal incremental cycle exercise test

| Variables        | Equations*                                           |
|------------------|------------------------------------------------------|
| \( VO_2 \), ml/min, male | \( W \times [50.75 - 0.372 \times A] \) |
| \( VO_2 \), ml/min, female | \( (W - 43) \times [22.78 - 0.17 \times A] \) |
| HR, beats/min    | \( 210 \times 0.65 \times A \star \)               |
| \( O_2 \) pulse, ml/beat | Predicated \( VO_2 \) max/predicted HRmax |
| \( Ve/MVV, \% \) | \( \sim 72 + 15 \)                                  |
| AT, L/min (\( VO_2 \)) | \( > 40 \% \) Predicated \( VO_2 \)       |

Definition of abbreviations: \( AT \) = Anaerobic threshold; HR = heart rate; \( Ve \) = minute ventilation; \( VO_2 \) = oxygen uptake.

Data from References 32, 33 and 34

* Age (A) : years; height (H) : centimeters; weight (W), kilograms.

Predicted weight men : \( 0.79 \times H - 60.7 \). Predicted weight women: \( 0.65 \times H - 42.8 \). When actual weight > predicted, the predicted weight should be used in the equations. Wasserman and colleagues introduced new corrections factors (34, 28), which have not yet been published in peer reviewed journals.

^ See Lange-Andersen and coworkers (345).

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