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FUNCTIONAL ASSESSMENT IN PULMONARY MEDICINE

Clinical Exercise Testing

- Increasingly being used in clinical practice:
  - Impact in the clinical decision making process
  - Resting cardiopulmonary measurements do not provide a reliable estimate of functional capacity
- Provide objective measures for diagnosis, treatment and prognosis

Types of Clinical Exercise Testing

- 6-minute walk test
- Shuttle walk test
- Exercise induced bronchoconstriction
- Cardiac stress test
- Cardiopulmonary exercise tests

Indications of 6MWT

- Before-and-after treatment comparisons
  - Lung resect^{n}, Tx
  - COPD, rehabilitat^{n}
- To measure functional status
  - HF, COPD, PVD
  - Cystic fibrosis
- To predict hospitalization and death
  - HF, COPD
  - Pulm HTN

Safety

- Absolute CI
  - USA or heart attack during previous month
- Relative CI
  - Resting tachycardia (HR 120 beats/min) or
  - Uncontrolled hypertension
- Physician need not be present
- Technician should be certified in CPR

Performing 6MWT

- Should be performed indoors along long, flat, straight corridors (30 m)
- Instruct and demonstrate properly
  - Walk AS FAR AS POSSIBLE for 6 minutes, but don't run or jog
  - Permitted to slow down, to stop, and to rest as necessary
  - May lean against the wall while resting
- Standard phrases for encouragement
  - "You are doing well"
  - "Keep up the good work"
- If practice test is done wait for ~1 hr, and report the highest 6MWD

Am J Respir Crit Care Med 2002;166:111–117

Variables Measured

- 6MWD
- Secondary measures include
  - Fatigue and dyspnea, measured by modified Borg or VAS
  - Arterial O_2 saturation
- Optimal reference equations from healthy population not yet available
- 6MWD range from 400 to 700 m
- Statistically significant mean increase in 6MWD in a group of COPD patients- 70 m

Am J Respir Crit Care Med 1997;155:1278–1282
Respir Care 2003;48(8):783–785

Interpretation

- A low 6MWD is nonspecific and non-diagnostic
- The following tests may then be helpful:
  - Pulmonary function
  - Cardiac function
  - Ankle–arm index
  - Muscle strength
  - Nutritional status
  - Orthopedic function
  - Cognitive function

WHY 6MWT ???

Walk tests

- **Time based tests**
  - 2MWT, 5MWT
  - 6MWT, 9MWT, 12MWT
- **Fixed distance tests**
  - 100 m, Half mile
  - 2 km walk test
- **Velocity determined tests**
- **Controlled pacing incremental tests**
  - Incremental shuttle walk test

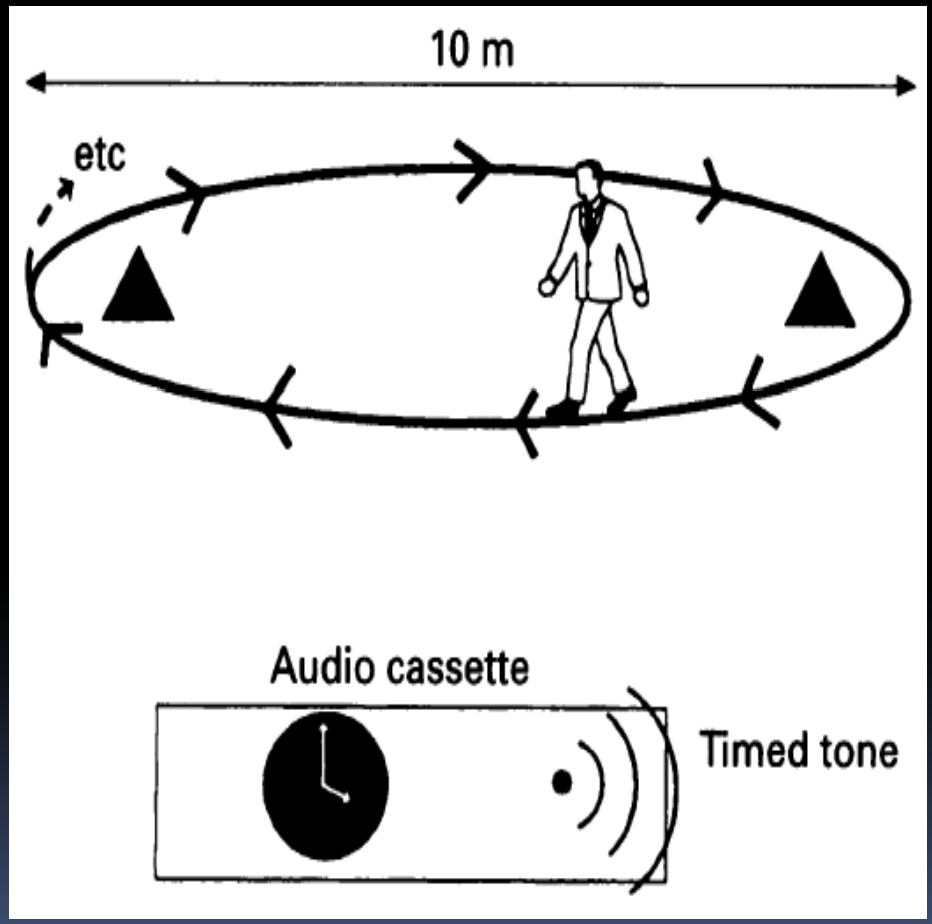
6MWT on treadmill

- Proposed when long corridor not available
- Advantages:
  - Continuous cardiovascular and oximetry monitoring
  - Ease of supplemental O_2 device carriage
- Disadvantages:
  - Difficult in elderly- coordination problems
  - Not interchangeable with conventional 6MWT (14% less 6MWD)
- If desired, an endurance constant work protocol at 0% elevation and steady speed is preferable

Am J Respir Crit Care Med 1999; 160:1540–1543

Shuttle walk test

- A walk test based on the 20m shuttle run test
- Measures maximal distance walked by the patient at a pace set by audio signals
- Requires patients to walk at increasing speeds up and down a 10m course
- Speed of walking is increased every minute (by 0.17 m/s)



Heart 1996;75:414-418

Shuttle walk test

- Terminated when pt becomes too breathless to maintain the required speed or if he fails to complete a shuttle in the time allowed
- Incremental maximal symptom-limited test
- Correlates better with VO_2max than 6MWT
- Disadvantages:
  - Does not reflect daily activities
  - Greater risk of complications than CPET (as no ECG)

Eur Respir J 1994;7:2016–2020

Endurance SWT

- Walk test for the assessment of endurance capacity of individuals
- Work rate of ESWT is set at 85% of maximal capacity which is obtained from a prior ISWT
- Constant work load field walking test which complements ISWT
- Field equivalents of the symptom limited laboratory exercise test
- While ISWT measures maximal capacity, ESWT examines the ability to use that capacity

Thorax 1999; 54:213–222

Field tests

- Shuttle walk
  - Better correlates VO2
  - Incremental
  - Maximal
- 6MWT
  - Easier, reliable
  - Safer
  - Submaximal
  - Self paced

- Measurement properties of the 6MWT have been the most extensively researched
- 6MWT is easy to administer, better tolerated, more reliable and responsive than 12MWT and 2MWT
- 6MWT more reflective of the requirements of activities of daily living
- Limited evidence on measurement properties of SPWT, SWT
- 6MWT should be the test of choice

Chest 2001;119;256-270

Exercise-Induced Bronchoconstriction Test

- Used to determine the presence of airway hyperreactivity
- FVC and FEV_1 measured at baseline and at 5, 15 and 30 min post exercise
- Positive test is reflected as a reduction of FEV_1 or FVC of 15% after exercise
- EIB observed in 70% to 80% of patients with clinically recognized asthma
- Less sensitive than methacholine challenge test

Cardiac Stress Test or Graded Exercise Test

- Most widely used clinical exercise testing modality in the United States
- Used primarily for the diagnosis of CAD and arrhythmias
- Performed on a treadmill- Bruce protocol is the most popular
- Single most reliable indicator of exercise-induced ischemia is ST-segment depression

CARDIOPULMONARY EXERCISE TESTING

CPET

(1) Objective determination of functional capacity & impairment

(2) Evaluation of the mechanisms of exercise limitation

(3) Differentiation between heart and lung disease

(4) Diagnosis of the causes of exercise intolerance and dyspnea on exertion

(5) Monitoring of disease progression and response to Rx

(6) Determination of the appropriate intensity needed to perform prolonged exercise

(7) Exercise prescription for cardiopulmonary rehabilitation

CPET

- Global assessment
  - Pulmonary
  - Cardiovascular
  - Hematopoietic
  - Neuro
  - Psychological
  - Skeletal muscle systems

Field tests

- Lack of reference values
- Absence of physiological measures
- Cannot differentiate system involvement

CPET

- Provides global assessment
- Can pinpoint system involvement
- Relatively noninvasive
- Dynamic physiologic overview
- Permits evaluation of both submaximal and peak exercise responses

When to perform

- Clinical decision
  - History, physical exam^{n}
  - CXR
  - ECG
  - PFT's

Clinical Indications

- Evaluation of exercise intolerance and unexplained dyspnea
- Cardiovascular diseases
- Respiratory diseases / symptoms
- Preoperative evaluation- lung resection, LVRS
- Pulmonary rehabilitation
- Impairment / disability assessment

Exercise Intolerance

- Assessment of exercise capacity
- Pathophysiologic basis of exercise limitation
- Contribution of cardiac / respiratory disease
- Symptoms disproportionate to routine tests

Cardiovascular & Pulmonary diseases

- Cardiovascular disease
  - Heart failure
  - Cardiac transplantation
  - Cardiac rehabilitation
- Respiratory disease
  - COPD, ILD, cystic fibrosis
  - PVD
  - For oxygen prescription

Preoperative evaluation

- Lung cancer resection surgery
  - VO_2 peak <50-60% predicted is associated with higher rates of morbidity and mortality after lung resection

    Am J Respir Crit Care Med 1999;159:1450–1456
- LVRS
  - Currently investigational
  - National Emphysema Treatment Trial- the maximal work rate derived from CPET as its primary physiologic outcome parameter

    Am J Respir Crit Care Med 2003;167:211-77

Contraindications

Absolute CI

- AMI (3-5 days) or USA
- Uncontrolled arrhythmia with HD compromise
- Syncope
- Respiratory or Heart failure
- Active endocarditis or myocarditis
- Severe AS
- PE or lower limb DVT
- Uncontrolled asthma

Relative CI

- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Severe untreated HTN (>200/120)
- Tachy or bradyarrhythmia/ AV block
- Hypertrophic cardiomyopathy
- Significant PAH
- Advanced pregnancy
- Orthopedic disease

Rate of death during testing 2-5/ lakh tests

Protocol

History, PFT, ECG

↓

Maximal incremental exercise on cycle ergometer

↓

Cardiopulmonary measurements

3 min resting

3 min unloaded cycling

10 min incremental/ Ramp

Exercise (5-30 W/min)

↓

10 min recovery

(3 min unloaded cycling)

ECG monitoring

Data collected

- Breath by breath analysis of VO_2, VCO_2 and V_E
- Electrocardiography
- Noninvasive blood pressure
- Pulse oximetry
- Arterial blood gas
- Invasive arterial BP

} sometimes

ABG monitoring

- Anaerobic threshold- Lactic acid measurements
- COPD / ILD / PVD (Significant desaturation)
- Oxygen prescription
- Accuracy of oximetry reduced when SpO_2 <88%

Variables measured by CPET

Variables	Noninvasive	Invasive
Work	Work rate	
Metabolic	VO_2 , VCO_2, RER, AT (A.K.A. LT)	Lactate
Cardiovascular	HR, HRR, ECG, BP, O_2 pulse	
Respiratory	V_E, V_T, VR, $PETO_2$, $PETCO_2$	
Pulmonary gas exchange	SpO_2 , V_E/VCO_2 , V_E/VO_2	SaO_2 , PaO_2 , $P(A\text{-}a)O_2$ V_D/V_T
Acid-base		pH, $PaCO_2$, HCO_3^-
Symptoms	Dyspnea, leg fatigue, chest pain	

Oxygen Uptake (VO_2)

- Best available index for the assessment of exercise capacity
- VO_2 max: when plateau is achieved
- VO_2 peak: VO_2 at max exercise, but no plateau
- Global assessment of respiratory, cardiac, blood & muscle function
- >84% predicted normally
  - Resting VO_2: 3.5 ml/kg/min (250 ml/min)
  - VO_2 max: 30-50 ml/kg/min (15 times basal)
  - Trained athletes: 80 ml/kg/min

Oxygen Uptake (VO_2)

- Decreased slope:
  - Inadequate O_2 transport/ utilization
  - Disease of heart, lung or circulation
  - Musculoskeletal disease
  - Poor effort

Am J Respir Crit Care Med 2003;167:211-77

CO_2 Output (VCO_2)

- CO_2 output depends on
  - Cardiac output
  - CO_2 carrying capacity
  - Tissue exchange
- CO_2 output more strongly dependent on ventilation than VO_2
- Resp exchange ratio
  = VCO_2 / VO_2

Am J Respir Crit Care Med 2003;167:211-77

Anaerobic Threshold

- *Lactate threshold or ventilatory threshold*
- Estimate of onset of metabolic acidosis during exercise (caused predominantly by increases in lactic acid)
- Indicates the upper limit of exercise that can be performed aerobically
- 50%–60% VO_2max in average persons (wide range of normal 35-80%)

Anaerobic threshold

- Noninvasive
  - V-slope method
  - Ventilatory equivalents method
- Invasive
  - Arterial lactate
  - Arterial bicarbonate

Anaerobic threshold

- Helpful as an indicator of level of fitness and to monitor the effect of physical training
- Reduced in a wide spectrum of clinical entities— so limited discriminatory value

Cardiac parameters

- CO increases linearly with VO_2 and does not vary with training- best indicator of cardiac function
- Initial ↑ in CO by ↑ HR and SV, later exclusively by ↑ HR
- Predicted maximum HR = 210 – (age × 0.65) or 220 - age
- Normally, max HR >90% age predicted
- HRR = Age predicted max HR – max HR achieved
- Normally, HRR <15 bpm

Oxygen pulse

- VO_2/ HR (n >80%)
- Amount of oxygen extracted per heart beat
- Reflects the product of SV & oxygen extraction
- Determined at plateau, when max oxygen extraction and SV have been reached

Am J Respir Crit Care Med 2003;167:211-77

Blood Pressure Response

- Decrease SVR, increase SBP, and typically normal DBP
- If blood pressure does not increase or declines
  - Cardiac limitation
  - Abnormality of sympathetic system
- Fall in BP during test- indication of termination

Ventilatory reserve

- Denotes potential ventilation in L that could be increased during exercise
- Difference or ratio between max minute ventilation (VEmax) and MVV
  - VEmax/MVV × 100 <75%
  - MVV – VEmax >11 L
- MVV can be measured directly or calculated (FEV_1 × 40)
- Pulmonary diseases have reduced reserve
- Cardiac diseases have normal reserve

VE and VO_2

- Relation complex
- Usually nonlinear

Am J Respir Crit Care Med 2003;167:211-77

VE and VCO_2

- Usually linear relationship
- Slope indicates ventilatory equivalent for VCO_2

Am J Respir Crit Care Med 2003;167:211-77

Ventilatory equivalent for VCO_2

- V_E/ VCO_2 denotes amount of V_E to eliminate 1L of VCO_2
- Noninvasive measurement of efficiency of ventilation
- Measured throughout but reported at AT (near nadir) when $PaCO_2$ is steady, to avoid the effect of hyperventilation acidosis
- Normally <34
- Suggests hyperventilation when a/w ↓ in $P_{ET}CO_2$ and increased V_D/V_T when ↑ in $P_{ET}CO_2$

End tidal PO_2 and PCO_2

- Isocapnic buffering: the period of increasing $P_{ET}O_2$ with relatively stable $P_{ET}CO_2$
  - Buffering of lactate (after AT) ↑ production of CO_2 and ventilation ↑ proportionately
  - So the alveolar & arterial CO_2 do not change
  - With further accumulation of lactate- V_E ↑ and CO_2 ↓

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CPET responses at peak exercise

	Resp COPD/ILD	Cardiac	PVD	Deconditioned
VO_2max	Decreased	Decreased	Decreased	Decreased
AT	N/ Decreased	Decreased	N/ Decreased	N/ Decreased
HRR	Increased	Decreased	N/ Decreased	N
V_E/MVV	Decreased	Normal	N	N
$P(A\text{-}a)O_2$	Increased	Normal	Increased	N

Interpretation: Integrative approach

- Review clinical and laboratory information
- Identify key variables: VEmax ,MVV, HR, SaO_2
- Compare exercise responses with appropriate normal reference values
- Evaluate cause of exercise limitation
- Patterns of exercise responses

Results are rarely clear-cut
Interpretation may be challenging

Cardiac disease

- Reduced work rate and VO_2peak
- Low AT (early onset metabolic acidosis)
- Low oxygen pulse
- High HR response (decrease HRR)
- Ventilatory reserve normal
- No desaturation

COPD

- Depends on stage of disease
- Reduced peak work rate and VO_2peak
- Reduced ventilatory reserve
- Peak HR reduced (significant HRR)
- Noninvasive AT : ABG may avoid false positive
- Reduced O_2 pulse- hemodynamic consequences of dynamic hyperinflation
- Hypoxemia- especially in emphysema (~DLCO)
- Hypercapnia (V/Q abnormalities and reduced drive in severe cases)

ILD

- Reduced peak work rate and peak VO_2
- AT (N)/ reduced
- Reduced ventilatory reserve
- Abnormal breathing pattern (high f, low V_T)
- Significant hypoxemia (~resting DLco)
- Wide $P(A\text{-}a)O_2$ gradient
- Low HRR- coexisting cor pulmonale

Pulmonary vascular disease

- Reduced peak work rate and peak VO_2
- AT reduced (early metabolic acidosis)
- Reduced oxygen pulse
- Ventilatory reserve normal
- HRR usually near normal (low- cor pulmonale)
- Significant hypoxemia
- Wide $P(A\text{-}a)O_2$ gradient

Deconditioning

- Reduced peak VO_2 (lower limit of N)
- Normal or low AT
- Reduced O_2 pulse
- Normal peak HR (no HRR)
- Normal ventilatory reserve
- Diff to distinguish from early cardiac disease - history and response to training
- May be coexistent with chronic diseases

Conclusions

- Exercise tests provide reliable estimate of functional capacity and activities of daily living
- Amongst walk tests 6MWT is test of choice
- CPET provide global assessment of various systems involved in exercise
- Interpretation to be done using integrative approach