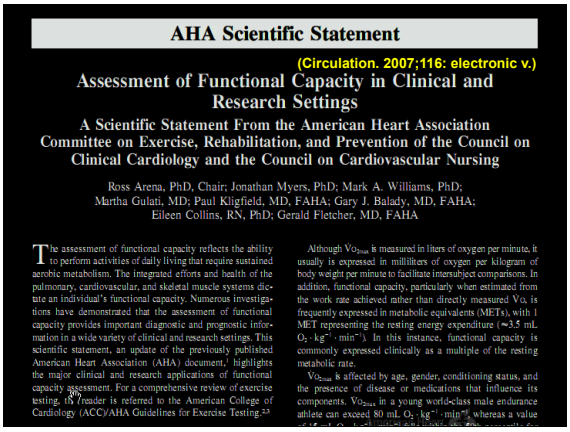
Exercise Evaluations: cardiovascular aspects

Visal Kantaratanakul, MD

Cardio-vascular testing

- Exercise ECG testing
- Aerobic testing: VO2 max, Sub-maximum
  - Direct/measured
  - Indirect/estimated
    - Walking/running test
    - Cycle test
    - Treadmill
    - Step test



AHA Scientific Statement

(Circulation. 2007;116: electronic v.)

Assessment of Functional Capacity in Clinical and Research Settings

A Scientific Statement From the American Heart Association Committee on Exercise, Rehabilitation, and Prevention of the Council on Clinical Cardiology and the Council on Cardiovascular Nursing

Ross Arena, PhD, Chair; Jonathan Myers, PhD; Mark A. Williams, PhD; Martha Gulati, MD; Paul Kligfield, MD, FAHA; Gary J. Balady, MD, FAHA; Eileen Collins, RN, PhD; Gerald Fletcher, MD, FAHA

The assessment of functional capacity reflects the ability to perform activities of daily living that require sustained aerobic metabolism. The integrated efforts and health of the pulmonary, cardiovascular, and skeletal muscle systems dictate an individual's functional capacity. Numerous investigations have demonstrated that the assessment of functional capacity provides important diagnostic and prognostic information in a wide variety of clinical and research settings. This scientific statement, an update of the previously published American Heart Association (AHA) document,[1] highlights the major clinical and research applications of functional capacity assessment. For a comprehensive review of exercise testing, the reader is referred to the American College of Cardiology (ACC)/AHA Guidelines for Exercise Testing.[2,3]

Although Vo_{2max} is measured in liters of oxygen per minute, it usually is expressed in milliliters of oxygen per kilogram of body weight per minute to facilitate intersubject comparisons. In addition, functional capacity, particularly when estimated from the work rate achieved rather than directly measured V_{O_2} is frequently expressed in metabolic equivalents (METs), with 1 MET representing the resting energy expenditure (≈3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$). In this instance, functional capacity is commonly expressed clinically as a multiple of the resting metabolic rate.

Vo_{2max} is affected by age, gender, conditioning status, and the presence of disease or medications that influence its components. Vo_{2max} in a young world-class male endurance athlete can exceed 80 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$, whereas a value

TABLE 3. Description and Metrics Used for Functional and Health Status Tools in Heart Failure

Measurement	Description	Metric
Peak $\dot{V}O_2$	Measured oxygen uptake	Continuous variable
Estimated METs	Multiple of RMR estimated from work rate achieved	Continuous variable
Weber scale[142]	Functional classification	5-Category scale based on peak $\dot{V}O_2$(A–E)
6-Minute walk[26]	Distance walked in 6 min	Meters
NYHA[143]	Functional classification	4-Category scale (1–4)
DASI[144]	Estimate of exercise tolerance	Transformed continuous variable in METs
VSAQ[145]	Pretest estimation of exercise capacity based on symptoms	13-Category scale using METs
KCCQ[89]	HF-specific health status measure with 8 domains	Transformed 0–100 scale
MLHFQ[146]	HF-specific QOL questionnaire	Continuous variable

RMR indicates resting metabolic rate; NYHA, New York Heart Association functional class; DASI, Duke Activity Status Index; VSAQ, Veterans Specific Activity Questionnaire; KCCQ, Kansas City Cardiomyopathy Questionnaire; MLHFQ, Minnesota Living with Heart Failure Questionnaire; HF, heart failure; and QOL, quality of life. Modified with permission from Myers et al.[93] Copyright © 2006, Elsevier.

TABLE 1. Functional Impairment During Incremental Treadmill Testing in Heart Failure: The Weber Classification

Class	Severity	Peak $\dot{V}O_2$, mL O_2 · kg^{-1} · min^{-1}	VT	CI max, L · min^{-1} · m^{-2}
A	Mild to none	>20	>14	>8
B	Mild to moderate	16–20	11–14	6–8
C	Moderate to severe	10–16	8–11	4–6
D	Severe	6–10	5–8	2–4
E	Very severe	<6	<4	<2

CI max indicates maximum cardiac index. Adapted with permission from Weber et al.[141] Copyright 1982, American Heart Association.

	Maximal, No Respiratory Gas Analysis	Maximal, Respiratory Gas Analysis	Submaximal, No Respiratory Gas Analysis	Walk Tests
Variables of interest	Duration	Peak/max $\dot{V}o_2$	Estimated METs	Distance walked
	Estimated METs	VT	ECG	
	ECG	$\dot{V}e/\dot{V}co_2$ slope	HR	
	Peak HR	Peak RER ($\dot{V}o_2/\dot{V}co_2$)	SBP and DBP	
	Peak SBP and DBP	PFT	Perceived exertion and dyspnea	
	HRR	Oxygen uptake/recovery kinetics		
	Pulse oximetry	Variables included in column 1		
	Perceived exertion and dyspnea			
Utility	General fitness assessment	Gold standard for assessing aerobic fitness	Estimation of aerobic testing when maximal testing not indicated (predischarge after acute MI)	Estimation of aerobic fitness
	Prognostic assessment	Prognostic assessment	Can be used to formulate exercise prescription	Measures response to medical or surgical intervention
	Exercise prescription	Classifies CHF severity		
		Decision tool for heart transplantation		
		Quantifies response to medical or surgical intervention		
		Differentiates cardiac vs pulmonary limitation		
Advantages	Modest cost	Best method for assessing aerobic fitness	Risk reduction vs maximal testing	Negligible cost
	Good reproducibility	Demonstrated prognostic value	Modest cost	Good reproducibility
	Demonstrated prognostic value	High reproducibility	Well tolerated	Well tolerated
		Assessment of ventilatory response to exercise		
Limitations	Influenced by familiarity with testing and handrail use	Higher cost and higher level of expertise	Indirect assessment of aerobic capacity	Influenced by familiarity with testing
	Less reliable than testing with respiratory gas analysis	Possible patient apprehension/discomfort	Shares weaknesses of maximal testing without respiratory gas analysis	
	Can overestimate aerobic capacity			

AHA Scientific Statement

Exercise Standards for Testing and Training

(*Circulation.* 2001; 104:1694-1740)

A Statement for Healthcare Professionals From the American Heart Association

Gerald F. Fletcher, MD, Chair; Gary J. Balady, MD, Vice Chair; Ezra A. Amsterdam, MD; Bernard Chaitman, MD; Robert Eckel, MD; Jerome Fleg, MD; Victor F. Froelicher, MD; Arthur S. Leon, MD; Ileana L. Piña, MD; Roxanne Rodney, MD; Denise G. Simons-Morton, MD, PhD; Mark A. Williams, PhD; Terry Bazzarre, PhD

The purpose of this report is to provide revised standards and guidelines for the exercise testing and training of individuals who are free from clinical manifestations of cardiovascular disease and those with known cardiovascular disease. These guidelines are intended for physicians, nurses, exercise physiologists, specialists, technologists, and other healthcare professionals involved in exercise testing and training of these populations. This report is in accord with the "Statement on Exercise" published by the American Heart Association (AHA).[1]

These guidelines are a revision of the 1995 standards of the AHA that addressed the issues of exercise testing and training.[2] An update of background, scientific rationale, and selected references is provided, and current issues of practical importance in the clinical use of these standards are considered.

(static), isotonic (dynamic or locomotory), and resistance (a combination of isometric and isotonic).[4,5] Isotonic exercise, which is defined as a muscular contraction resulting in movement, primarily provides a volume load to the left ventricle, and the response is proportional to the size of the working muscle mass and the intensity of exercise. Isometric exercise is defined as a muscular contraction without movement (eg, handgrip) and imposes greater pressure than volume load on the left ventricle in relation to the body's ability to supply oxygen. Cardiac output is not increased as much as in isotonic exercise because increased resistance in active muscle groups limits blood flow. Resistance exercise combines both isometric and isotonic exercise (such as free weight lifting).

1997 Exercise Testing Guideline Recommendation	2002 Exercise Testing Guideline Recommendation
Class I	***Class I***
1. Before discharge for prognostic assessment, activity prescription, evaluation of medical therapy (submaximal at about 4 to 7 days).*	1. Before discharge for prognostic assessment, activity prescription, evaluation of medical therapy (submaximal at about 4 to 6 days).*
2. Early after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the predischarge exercise test was not done (symptom limited; about 14 to 21 days).*	2. Early after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the predischarge exercise test was not done (symptom limited; about 14 to 21 days).*
3. Late after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the early exercise test was submaximal (symptom limited; about 3 to 6 weeks).*	3. Late after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the early exercise test was submaximal (symptom limited; about 3 to 6 weeks).*
Class IIa	***Class IIa***
1. After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization.	1. After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization.
Class IIb	***Class IIb***
1. Before discharge in patients who have undergone cardiac catheterization to identify ischemia in the distribution of a coronary lesion of borderline severity.	
2. Patients with the following ECG abnormalities: • Complete left bundle-branch block • Pre-excitation syndrome • Left ventricular hypertrophy • Digoxin therapy • Greater than 1 mm of resting ST-segment depression • Electronically paced ventricular rhythm	1. Patients with the following ECG abnormalities: • Complete left bundle-branch block • Pre-excitation syndrome • Left ventricular hypertrophy • Digoxin therapy • Greater than 1 mm of resting ST-segment depression • Electronically paced ventricular rhythm
3. Periodic monitoring in patients who continue to participate in exercise training or cardiac rehabilitation.	2. Periodic monitoring in patients who continue to participate in exercise training or cardiac rehabilitation.
Class III	***Class III***
1. Severe comorbidity likely to limit life expectancy and/or candidacy for revascularization.	1. Severe comorbidity likely to limit life expectancy and/or candidacy for revascularization. 2. At any time to evaluate patients with acute myocardial infarction who have uncompensated congestive heart failure, cardiac arrhythmia, or noncardiac conditions that severely limit their ability to exercise. *(Level of Evidence: C)* 3. Before discharge to evaluate patients who have already been selected for, or have undergone, cardiac catheterization. Although a stress test may be useful before or after catheterization to evaluate or identify ischemia in the distribution of a coronary lesion of borderline severity, stress imaging tests are recommended. *(Level of Evidence: C)*

- Left ventricular hypertrophy
- Digoxin therapy
- Greater than 1 mm of resting ST-segment depression
- Electronically paced ventricular rhythm

3. Periodic monitoring in patients who continue to participate in exercise training or cardiac rehabilitation.

Class III

1. Severe comorbidity likely to limit life expectancy and/or candidacy for revascularization.

- Left ventricular hypertrophy
- Digoxin therapy
- Greater than 1 mm of resting ST-segment depression
- Electronically paced ventricular rhythm

2. Periodic monitoring in patients who continue to participate in exercise training or cardiac rehabilitation.

Class III

1. Severe comorbidity likely to limit life expectancy and/or candidacy for revascularization.

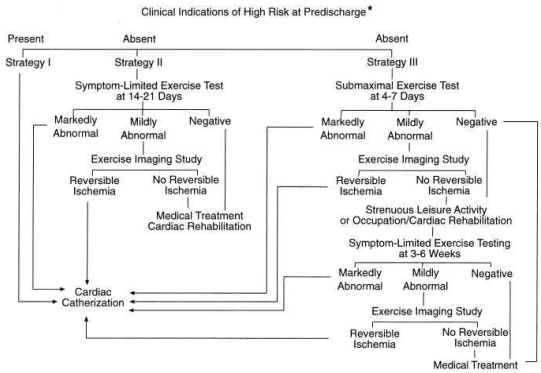
2. At any time to evaluate patients with acute myocardial infarction who have uncompensated congestive heart failure, cardiac arrhythmia, or noncardiac conditions that severely limit their ability to exercise. *(Level of Evidence: C)*

3. Before discharge to evaluate patients who have already been selected for, or have undergone, cardiac catheterization. Although a stress test may be useful before or after catheterization to evaluate or identify ischemia in the distribution of a coronary lesion of borderline severity, stress imaging tests are recommended. *(Level of Evidence: C)*

*Exceptions are noted under Classes IIb and III.

Submaximal/symptom-limited tests

- protocols with a predetermined end point,
  - peak heart rate of 120 beats/min
  - 70% predicted maximum heart rate
  - a peak MET level of 5.
- Symptom-limited tests are designed to continue until the patient demonstrates abnormal signs and/or symptoms that necessitate termination of exercise.



IV. After Myocardial Infarction

Class I

1. Before discharge for prognostic assessment, activity prescription, evaluation of medical therapy (submaximal at about 4 to 7 days).*
2. Early after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the predischarge exercise test was not done (symptom-limited/about 14 to 21 days).*
3. Late after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the early exercise test was submaximal (symptom-limited/about 3 to 6 weeks).*

Class IIa

1. After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization.

American Thoracic Society

ATS Statement: Guidelines for the Six-Minute Walk Test

THIS OFFICIAL STATEMENT OF THE AMERICAN THORACIC SOCIETY WAS APPROVED BY THE ATS BOARD OF DIRECTORS MARCH 2002

CONTENTS

PURPOSE AND SCOPE

This statement provides practical guidelines for the 6-minute walk test (6MWT). Specifically, it reviews indications, details factors that influence results, presents a brief step-by-step protocol, outlines safety measures, describes proper patient preparation and procedures, and offers guidelines for clinical inter-

pulmonary exercise test (1, 2). Other professional organizations have published standards for cardiac stress testing (3, 4).

Assessment of functional capacity has traditionally been done by merely asking patients the following: "How many flights of stairs can you climb or how many blocks can you walk?" However, patients vary in their recollection and may report overestimations or underestimations of their true functional capacity. Objective measurements are usually better than self-reports. In the early 1960s, Balke developed a simple test to evaluate the functional capacity by measuring the distance walked during a defined period of time (5). A 12-minute field performance test was then developed to evaluate the level of physical fitness of healthy individuals (6). The walking test was also adapted to assess disability in patients with chronic bronchitis (7). In an attempt to accommodate patients with respiratory disease for whom walking 12 minutes was too exhausting, a 6-minute walk was found to perform as well as the 12-minute walk (8). A recent review of functional walking tests concluded that "the 6MWT is easy to administer, better tolerated, and more reflective of activities of daily living than the other walk tests" (9).

6-minute walk test(6MWT)

- a functional test to evaluate exercise capacity
  - patients with marked LV dysfunction
  - peripheral arterial occlusive disease
  - very low level of endurance
- cannot perform cycle ergometer or treadmill exercise.

INDICATIONS FOR THE SIX-MINUTE WALK TEST

- Pretreatment and post treatment comparisons
- Functional status (single measurement)
- Predictor of morbidity and mortality

Pretreatment and post treatment comparisons

- Lung transplantation
- Lung resection
- Lung volume reduction surgery
- Pulmonary rehabilitation
- COPD
- Pulmonary hypertension
- Heart failure

Functional status (single measurement)

- **COPD**
- **Cystic fibrosis**
- **Heart failure**
- **Peripheral vascular disease**
- **Fibromyalgia**
- **Older patients**

Predictor of morbidity and mortality

- Heart failure
- COPD
- Primary pulmonary hypertension

REQUIRED EQUIPMENT

- Countdown timer (or stopwatch)
- Mechanical lap counter
- Two small cones to mark the turnaround points
- A chair that can be easily moved along the walking course
- Worksheets on a clipboard
- A source of oxygen
- Sphygmomanometer
- Telephone
- Automated electronic defibrillator

- Patients are instructed to walk down a 100-foot corridor at their own pace, attempting to cover as much ground as possible in 6 minutes.
- At the end of the 6-minute interval, the total distance walked is determined and the symptoms experienced by the patient are recorded.

" The object of this test is to walk as far as possible for 6 minutes. You will walk back and forth in this hallway. Six minutes is a long time to walk, so you will be exerting yourself. You will probably get out of breath or become exhausted. You are permitted to slow down, to stop, and to rest as necessary. You may lean against the wall while resting, but resume walking as soon as you are able. You will be walking back and forth around the cones. You should pivot briskly around the cones and continue back the other way without hesitation. Now I'm going to show you. Please watch the way I turn without hesitation"

- After the first minute, tell the patient the following (in even tones):

"You are doing well. You have 5 minutes to Go"

- When the timer shows 4 minutes remaining, tell the patient the following:

"Keep up the good work. You have 4 minutes to go"

- When the timer shows 3 minutes remaining, tell the patient the following:

"You are doing well. You are halfway done"

- When the timer shows 2 minutes remaining, tell the patient the following:

"Keep up the good work. You have only 2 minutes left"

- When the timer shows only 1 minute remaining, tell the patient:

"You are doing well. You have only 1 minute to go"

- Do not use other words of encouragement (or body language to speed up).

6MWT

- **uses a submaximal level of stress**
- **A warm-up period before the test should not be performed.**
- **correlates only modestly with VO2 max.**
- **ECG monitoring is not routinely done**
- **limiting its diagnostic accuracy.**

- patients with pulmonary disease, the distance is highly reproducible (*r*50.86 to 0.95) and correlates moderately well with peak V˙ O2 (*r*50.52 to 0.71).
- reproducibility of timed-walk tests is generally good, with intrasubject coefficients of variation averaging < 10%

Reasons for immediately stopping

- chest pain
- intolerable dyspnea
- leg cramps
- staggering
- Diaphoresis
- pale or ashen appearance.

ELSEVIER

The European Journal of Heart Failure 6 (2004) 687–691

The European Journal of Heart Failure

www.elsevier.com/locate/heafai

Review

The 6 minute walking test in chronic heart failure: indications, interpretation and limitations from a review of the literature

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Received 22 January 2003; received in revised form 4 November 2003; accepted 26 November 2003
Available online 5 June 2004

Table 1
Reference equation for the distance walked during the 6-min walking test in adult healthy subjects

Men

$6MWD = (7.57 \times height_{cm}) - (1.76 \times weight_{kg}) - (5.02 \times age) - 309$ m

Alternate equation using the body mass index (BMI, expressed in kg/m^2):

$6MWD = 1140$ m $- (5.61 \times BMI) - (6.94 \times age)$

With both equations subtract 153 m to obtain the lower limit of normal

Women

$6MWD = (2.11 \times height_{cm}) - (2.29 \times weight_{kg}) - (5.78 \times age) + 667$ m

Alternate equation using the body mass index (BMI, expressed in kg/m^2):

$6MWD = 1017$ m $- (6.24 \times BMI) - (5.83 \times age)$

With both equations subtract 139 m to obtain the lower limit of normal

Modified from Enright et al. Am J Respir Crit Care Med 1998; 158: 1384.

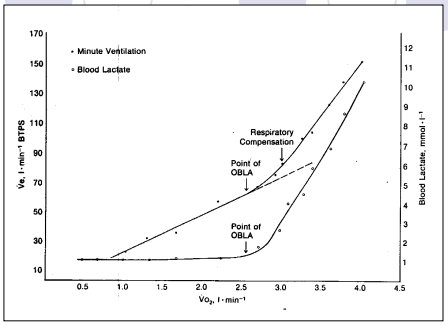
The prognostic significance of the 6MWT

- Lower levels of functional capacity

(a distance<300 m during 6MWT)

In SOLVD study

- total mortality was10.23% in subjects with a 6MWT<300 m
- 2.99% in subjects with a 6MWT ≥ 450



Factors effcting oxygen max

- Age
- Sex
- Exercise habits
- Genetics
- Cardiovascular clinical status

TABLE 1. Normal Values of Maximal Oxygen Uptake at Different Ages

Age, y		Men	Women
20–29			
	mL · kg⁻¹ · min⁻¹	43±7.2	36±6.9
	METs	12	10
30–39			
	mL · kg⁻¹ · min⁻¹	42±7.0	34±6.2
	METs	12	10
40–49			
	mL · kg⁻¹ · min⁻¹	40±7.2	32±6.2
	METs	11	9
50–59			
	mL · kg⁻¹ · min⁻¹	36±7.1	29±5.4
	METs	10	8
60–69			
	mL · kg⁻¹ · min⁻¹	33±7.3	27±4.7
	METs	9	8
70–79			
	mL · kg⁻¹ · min⁻¹	29±7.3	27±5.8
	METs	8	8

Values are expressed as mean±SD. MET indicates metabolic equivalent or 3.5 mL O_2 · kg⁻¹ · min⁻¹.

ข้อบ่งชี้ว่าเป็นค่าการใช้ออกซิเจนสูงสุด

- **เมื่อการวัดการใช้ออกซิเจนไม่เพิ่มขึ้นหรือเพิ่มน้อยกว่า 150 ml/minเมื่อเพิ่มงานมากขึ้น**
- **เมื่อค่า อัตราการแลกเปลี่ยนก๊าซ (RER) มากกว่า 1**

Maximal oxygen uptake measurement

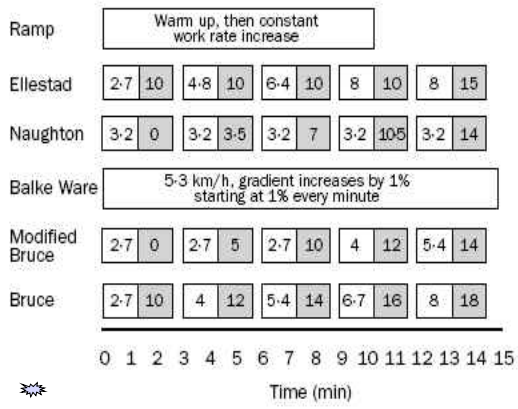
- **VO2 max : a leveling -off or peaking - over in oxygen uptake during creasing exercise intensity**

  attainment maximum capacity for aerobic metabolism
- **VO2peak ; peak oxygen uptake : the highest oxygen uptake value during the test**

Exercise Mode and Protocol Selection

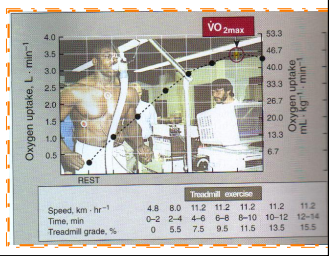
- Treadmill
- Cycle
- Arm cycle

treadmill MET= 0.98(cycle ergometer METs) + 1



Tests of Vo2 max

- Continue 3-5 min
- supramaximal
- exhaustion
- psychologic & motivation



Maximal oxygen uptake predictions walking test

- **VO2 max in L.min -1**

= 6.9652+(0.0091 x W)-(0.0257 x A)+ (0.5955 X G)

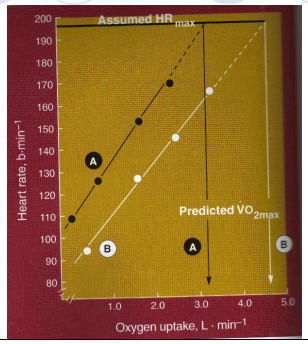
- (0.224xT1) - (0.0051x HR max)

- **VO 2 max in ml.kg -1.min-1**

=132.853-(0.0769 x W)-(0.3877 x A)+ (6.315 x G) -

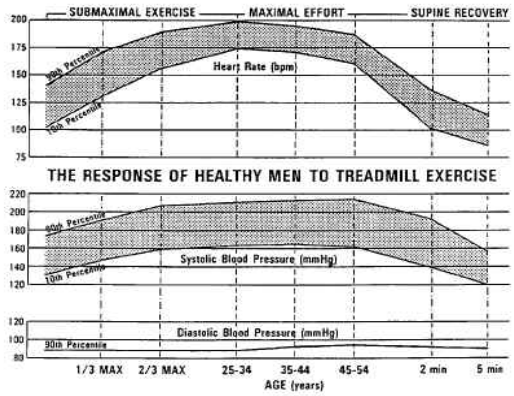
(3.2649 x T)-(0.1565 x HR peak)

Heart rate predictions of VO 2 max



Limit the accuracy of predicting VO 2 max

- **Linearity of the HR - VO2 relationship**
- **similar maximum heart rates for all subjects**
- **assumed constant exercise economy**
- **day -to- day variation in exercise heart rate**



Panel 3: **Indications for the use of gas-exchange measurements in exercise testing**

Criteria	Methodology
Class I Disorders for which there is evidence and/or general agreement that given procedure or treatment is useful and effective	Assessment of exercise capacity and response to therapy in patients with heart failure who are being considered for heart transplantation Assistance in the differentiation of cardiac versus pulmonary exercise-induced dyspnoea or impaired exercise capacity when cause is uncertain
Class II Disorders for which there is conflicting evidence and/or divergence of opinion about the usefulness/efficacy of procedure or treatment	
IIa Weight of evidence/opinion in favour of usefulness/efficacy	Assessment of exercise capacity when indicated for medical reasons in patients in whom subjective assessment of maximum exercise is unreliable

Panel 3: **Indications for the use of gas-exchange measurements in exercise testing**

Criteria	Methodology
IIb	
Usefulness/efficacy less well established by evidence/opinion	Assessment of patient's response to specific therapeutic interventions in which improvement of exercise tolerance is important goal or end point
	Determination of the intensity of exercise training as part of comprehensive cardiac rehabilitation
Class III	
Disorders for which there is evidence and/or general agreement that procedure/ treatment is not useful/effective and in some cases may be harmful	Routine use to assess exercise capacity

TABLE 4. Cardiopulmonary Exercise Test Parameters Used to Differentiate Cardiac and Pulmonary Causes of Exertional Dyspnea

	Cardiac	Pulmonary
Peak $\dot{V}o_2$	Reduced	Reduced
VT	May be reduced	May be reduced
$V_{E\ MAX}$	≤80% of MVV	>80% of MVV*
Spo_2	>90% throughout exercise	May drop to <90%*
CO	May be reduced	Normal
Pre-exercise PFT	Normal	May have obstructive or restrictive pattern*
FEV_1 postexercise	No change from pre-exercise	≥15% decrease from pre-exercise†
PEF postexercise	No change from pre-exercise	≥15% decrease from pre-exercise†

MVV indicates maximal voluntary ventilation; PFT, pulmonary function test; and PEF, peak expiratory flow.

*These responses should not be considered the gold standard for defining a pulmonary limitation to exercise. Rather a Vemax >80% of MVV, a drop in Spo_2, and/or abnormal resting PFT values indicate a pulmonary limitation that must be supported by additional testing (rule out cardiac shunts, coexisting cardiac and pulmonary disease, etc).

†Compatible with exercise-induced bronchospasm.