Normal and Abnormal Exercise Response

Potential Measurements

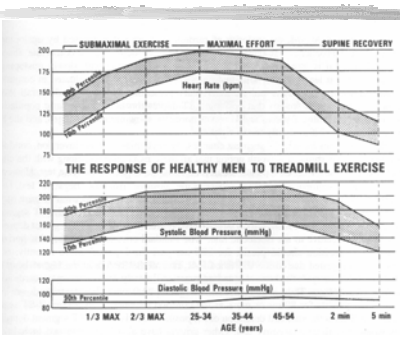
- **Signs and symptoms**
- **Heart rate and blood pressure**
- **EKG**
- **Cardiac output, stroke volume**
- **VO2**
- **Anaerobic threshold**
- **O2 pulse**
- **Systolic time interval**
- **Skin temperature**
- **Wall motion**
- **Heart sounds**

- **Not just HR and BP!!**

Signs and Symptoms

- Normal Response
  - flush skin, moist
  - shortness of breathe, local muscular fatigue
- Abnormal Response (CAD)
  - cool, clammy skin
  - peripheral cyanosis
  - dizziness, ataxia, nausea, confusion
  - angina during exercise, disappears in recovery

Heart Rate and Blood Pressure



ACSM Fig 6-1

Normal Peak Blood Pressures

TABLE 6-1. Mean (±SD) Peak SBP and DBP (mm Hg) During Maximal Treadmill Exercise*

	Men		Women	
Age	SBP	DBP	SBP	DBP
18–29	182 ± 22	69 ± 13	155 ± 19	67 ± 12
30–39	182 ± 20	76 ± 12	158 ± 20	72 ± 12
40–49	186 ± 22	78 ± 12	165 ± 22	76 ± 12
50–59	192 ± 22	82 ± 12	175 ± 23	78 ± 11
60–69	195 ± 23	83 ± 12	181 ± 23	79 ± 11
70–79	191 ± 27	81 ± 13	196 ± 23	83 ± 11

*Reprinted with permission from Hiroyuki D, Allison TG, Squires RW, et al. Peak exercise blood pressure stratified by age and gender in apparently healthy subjects. Mayo Clin Proc 1996;71:445–452.

Abnormal HR and BP responses

- ↑HR response
  - poor conditioning, dysrhythmia
- ↓HR response
  - conduction defect, ischemia, LV dysfunction
- ↑BP response (>225/90)
  - future hypertensive
- ↓SBP (exercise-induced hypotension)
  - valve disease, CAD, LV dysfunction

CAD HR and BP ex response

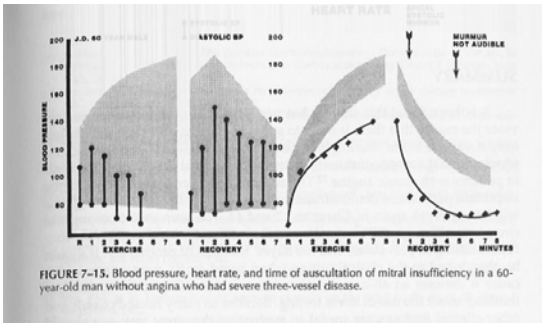


FIGURE 7–15. Blood pressure, heart rate, and time of auscultation of mitral insufficiency in a 60-year-old man without angina who had severe three-vessel disease.

Delta Heart Rate

⌘Difference between resting and maximal HR response

⌘The lower the delta HR, the higher the mortality

Pressure Pulse Product (Double Product)

⌘SBP x HR

⌘Index of myocardial oxygen consumption

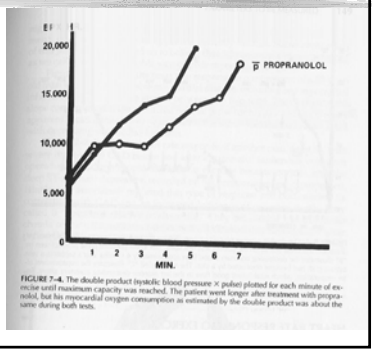


FIGURE 7–4. The double product (systolic blood pressure × pulse) plotted for each minute of exercise until maximum capacity was reached. The patient went longer after treatment with propranolol, but his myocardial oxygen consumption as estimated by the double product was about the same during both tests.

Double Product and coronary artery occlusion

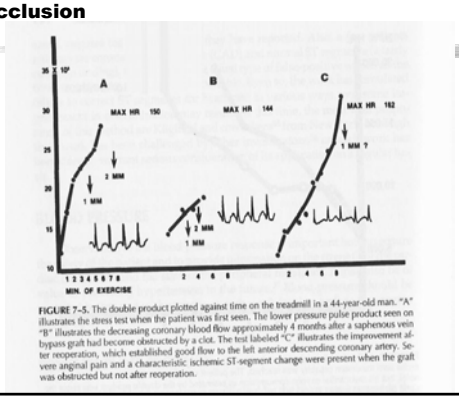


FIGURE 7–5. The double product plotted against time on the treadmill in a 44-year-old man. "A" illustrates the stress test when the patient was first seen. The lower pressure pulse product seen on "B" illustrates the decreasing coronary blood flow approximately 4 months after a saphenous vein bypass graft had become obstructed by a clot. The test labeled "C" illustrates the improvement after reoperation, which established good flow to the left anterior descending coronary artery. Severe anginal pain and a characteristic ischemic ST-segment change were present when the graft was obstructed but not after reoperation.

Cardiac Output, Stroke Volume

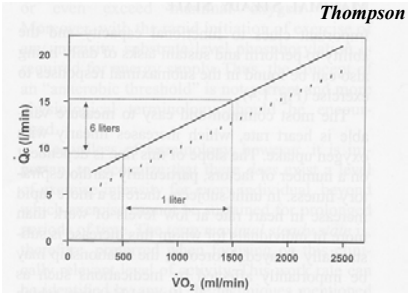
⌘Invasive measures: Swan-Ganz catheter is introduced into the pulmonary artery

- Flow sensor: direct Fick
- Thermistor: thermal dilution

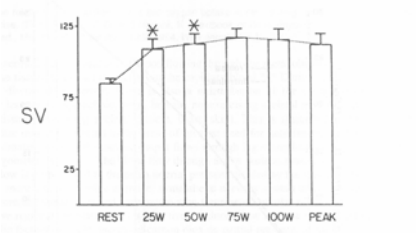
⌘Non-invasive measures: rebreathing techniques, continuous-wave Doppler

Cardiac Output vs. Work Rate

Thompson 01, pg 5

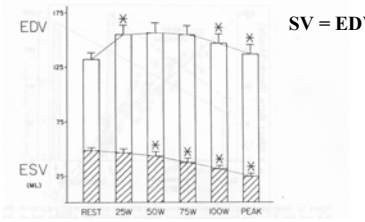


Normal Stroke Volume Response



In upright position, SV increases initially with exercise

EDV and ESV during exercise



SV = EDV -ESV

Increase SV with exercise is due to ↑EDV and ↓ESV

Cardiac Contractility

- Ejection Fraction
  - EF = EDV - ESV / EDV
    - resting value about 60%
    - exercise value, increases to 80-85%
- ESV
  - volume of blood left in the heart after contraction

CAD CO, HR, and SV responses

- CAD patients may have constriction in coronary arteries
- Constriction causes ischemia and ↓pump fn
- Cardiac output may not rise normally
- SV may not increase normally
- HR response may be blunted (independent of drugs) and may even decrease

Why are VO2 measurements obtained?

- VO2 measurement is more reliable than estimates from cycle or treadmill eqns
- Peak VO2 is most accurate measurement of functional capacity and index of overall cardiopulmonary health
- Heart and lung diseases will be evident from gas exchange abnormalities

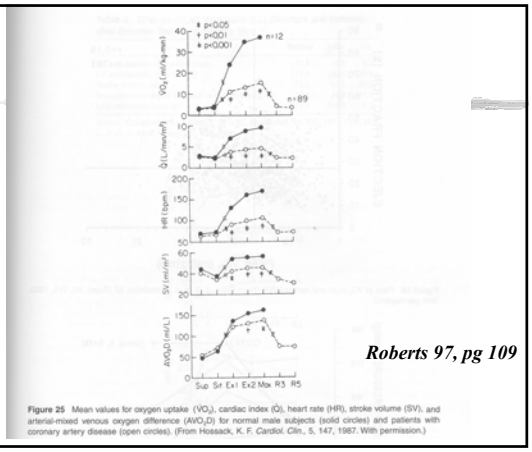
Oxygen Consumption

- The most notable result of CAD is ↓VO2max
  - variable response (depends on amount of myocardium involved and severity of ischemia)
- ↓ VO2 at submaximal levels of exercise
- oxygen kinetics are slower
- more reliance on anaerobic energy production during exercise

Maximal Exercise O2 variables

Subject	VO2 ml/min	HR bpm	SV ml/b	CO l/min	a-vO2 ml/dl
CAD	1500	175	50	8.8	17.0
Normal	3000	190	100	19.0	15.8
Athlete	5600	180	180	32.5	17.0

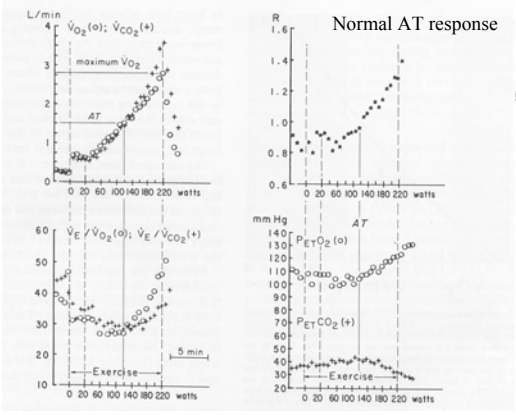
Roberts 97, pg 106



Roberts 97, pg 109

Anaerobic threshold or ventilatory threshold

- AT has been described as the breakpt in Ve associated with lactate accumulation and muscle anaerobiosis
- AT probably reflects a balance between lactate production and removal
- Exercise beyond AT is associated with metabolic acidosis, hyperventilation, and reduced capacity to perform work



Wasserman86, pg 35

AT response in CAD

- AT < 40%VO2max is below 95% confidence for sedentary subjects
- ↓ AT is assoc with CAD and is a sign of a condition that limits O2 flow to muscles
- Other tests are needed to differentiate whether problem is cardiovascular, respiratory or metabolic

O2 pulse

- O2 pulse = VO2/HR
- O2 pulse = SV x a-vO2 difference
- With exercise, O2 pulse increases due to ↑ a-v O2 difference and SV (upright)
- In CAD, the rise in O2 pulse is blunted because SV is reduced

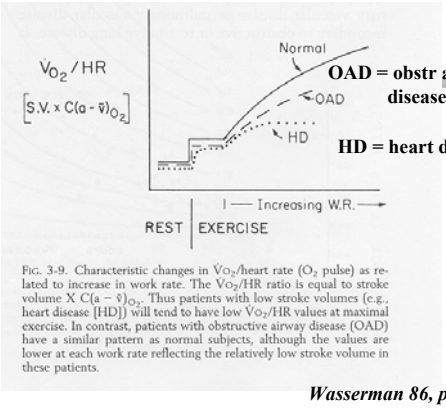


FIG. 3-9. Characteristic changes in $\dot{V}O_2$/heart rate (O_2 pulse) as related to increase in work rate. The $\dot{V}O_2$/HR ratio is equal to stroke volume X $C(a-\bar{v})_{O_2}$. Thus patients with low stroke volumes (e.g., heart disease [HD]) will tend to have low $\dot{V}O_2$/HR values at maximal exercise. In contrast, patients with obstructive airway disease (OAD) have a similar pattern as normal subjects, although the values are lower at each work rate reflecting the relatively low stroke volume in these patients.

OAD = obstr airways disease

HD = heart disease

Wasserman 86, pg 37

Skin Temperatures

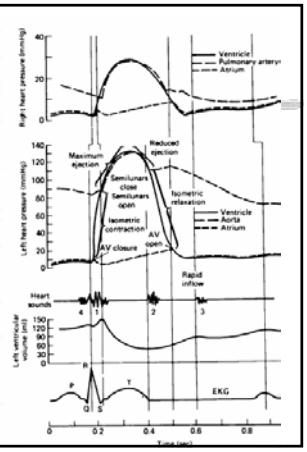
- Skin temperatures measured on the chest
  - Thermistors
  - Thermoscan
- During angina, a cold area develops over the heart due to vasoconstriction
- Appears about 1 min before pain

Systolic Time Intervals

- Measure by
  - Phonocardiogram
  - Carotid pulse sensor
  - Ballistocardiogram
- Prolonged STI could indicate coronary insufficiency, decreased ventricular function, increased TPR, abnormal wall motions

Heart Sounds

1. A-V valves close at onset of systole, blood rumbling (lub)
2. Aortic then pulmonic valves close at onset of diastole (dub)
3. Rapid filling in early diastole, sound occurs with decreased ventricular distensibility
4. Atrial contraction



Bad Heart Sounds

- **Sound 1,** should be loud and powerful
  - Mitral murmur, prolapsed mitral leaflet (10% of pop)
- **Sound 2,** splitting may be LBBB and decreased right or left ventricle function
  - Aortic murmur, aortic stenosis
- **Sound 3,** associated with poor ventricular function
- **Sound 4,** common in ischemic heart disease or myocardial disease.

Conclusions:

- The predictive value of exercise testing is improved by considering exercise responses in addition to EKG
  - Reduced VO2max
  - Blunted hemodynamic response
  - Lowered AT
  - Lowered O2 pulse
  - Prolonged STI
  - Unusual sounds or palpations