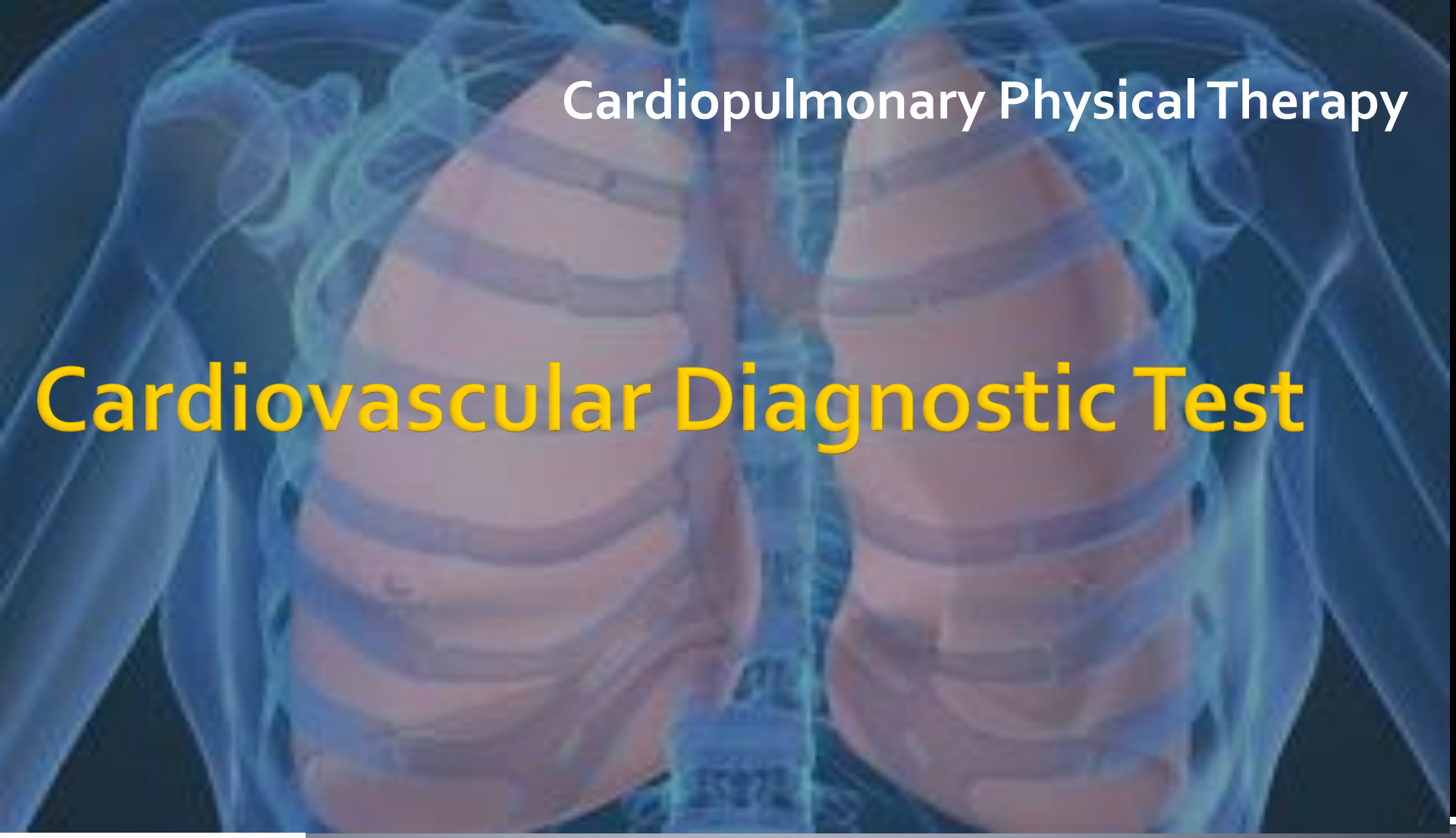

Cardiopulmonary Physical Therapy

Cardiovascular Diagnostic Test

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Haneul Lee, DSc, PT

Cardiovascular Diagnostic Tests

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- **Clinical Laboratory Studies**
- Other Noninvasive Diagnostic Tests
- Other Imaging Modalities
- **Exercise Testing**
- Pharmacologic Stress Testing
- Cardiac Catheterization : Coronary Angiography and Ventriculography
- Digital Subtraction Angiography
- Endocardial Biopsy
- Vascular Diagnostic Testing for Aortic, Peripheral, and Carotid Disease
- **Peripheral Arterial Disease and Dysfunction and Diagnosis**

Exercise Screening Review

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- Primary diagnosis
- Setting of patient care
- Always perform baseline testing
- Monitor
  - HR, BP, RPE,ECG and maybe SaO_2, dyspnea scale
  - Pre, during, and post exercise
  - Document, document, and document

Exercise Tolerance Test (ETT)

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- An **Exercise Tolerance Test (ETT)** or **Exercise Stress Test** is used to provide information about how the heart responds to stress

http://www.askdoctork.com/what-is-an-exercise-stress-test-20111209755

Exercise Stress Test Explained Simply

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www.Doctorsecrets.com , https://www.youtube.com/watch?v=VJyRGOP3Gyk

Exercise Tolerance Testing

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- Purpose
  - to determine ***physiological responses*** during a measured exercise stress (increasing workloads); allows the determination of **functional exercise capacity** of an individual

https://pancreaticcanceraction.org/wp-content/uploads/2015/02/exercise-tolerance-test-360x240.jpg

Exercise Tolerance Testing

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- Severs as a basis for exercise prescription. Symptom-limited ETT is typically administered prior to start of cardiac rehabilitation program and following cardiac rehabilitation as an outcome measure.
- Used a s a screening measure for CAD in asymptomatic individuals
- ETT with radionuclide perfusion : assists in the diagnosis of suspected or established cardiovascular disease

Indications for ETT

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- Evaluation of **chest pain** suggestive of CAD
- Evaluation of **atypical chest pain**
- Determination of **prognosis and severity** of CAD
- Evaluation of the effects of medical or surgical **therapy or intervention**
- Evaluation of **arrhythmias**
- Evaluation of **hypertension with activity**
- Assessment of **functional capacity**
- Screening to provide an **exercise prescription**
- Providing **motivation** for a lifestyle change to reduce the risk of developing CAD

Arrhythmias

- An **abnormal** heart rhythm
- During an arrhythmia, the heart can beat too fast, too slow, or with an irregular rhythm
- A heartbeat that is too fast is called **tachycardia**
- A heartbeat that is too slow is called **bradycardia**
- Most arrhythmias are harmless, but some can be **serious or even life threatening**
- During an arrhythmia, the heart may **not** be able to pump **enough blood** to the body. Lack of blood flow can damage the brain, heart, and other organs.

ETT Testing modes

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- **Treadmill** and **cycle ergometer** (leg or arm test) allow for precise calibration of the exercise workload.

http://www.fitnesszone.com/Merchant2/graphics/00000001/first-degree-e-920-upper-body-ergometer-4_2.jpg

http://www.control.tu-berlin.de/wiki/images/4/43/reha_move.jpg

Exercise Testing modes

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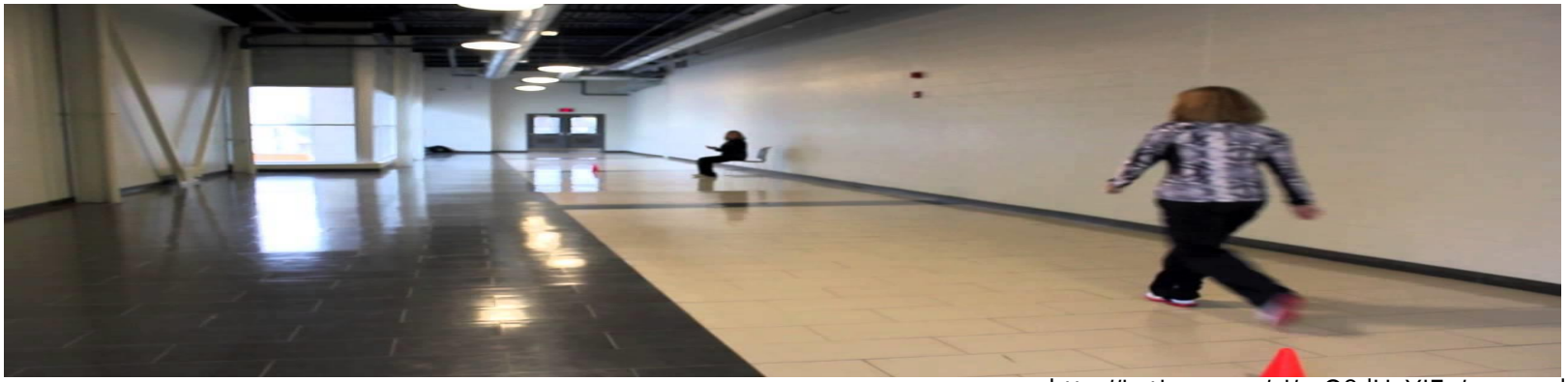
- **Step test** can also be used for fitness screening, healthy population

testcapacidadfisicaterceraedad.blogspot.com

- **Walk test**
  - 6 or 12 minute walk test



http://i.ytimg.com/vi/n-O8dHyYIFo/maxresdefault.jpg

Exercise Tolerance Testing

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- ETT may be **maximal** or **submaximal**
  - **Maximal ETT** : defined by target endpoint heart rate
    - Age-adjusted maximum heart rate (AAMHR)

      : **220 – age of individual**
    - Heart-rate range (Karvonen's formula)

      : **60-80% (HR max – resting HR) + resting HR = target HR**
  - **Submaximal ETT** : symptom-limited; used to evaluate the early recovery of patients after MI, coronary bypass, or coronary angioplasty

Exercise Tolerance Testing

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- Low-level ETT
  - Usually performed when patients have experienced an MI recently or have undergone CABG
- Continuous ETT
  - Workload is steadily progressed usually in 2 or 3 minute stages.
- Discontinuous ETT
  - Allows rest in between workloads/stages; used for patients with more pronounced CAD

Exercise Tolerance Testing

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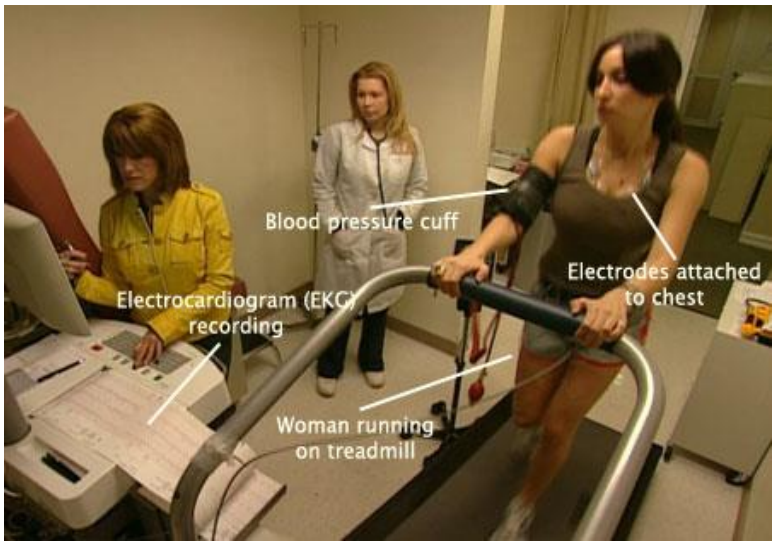
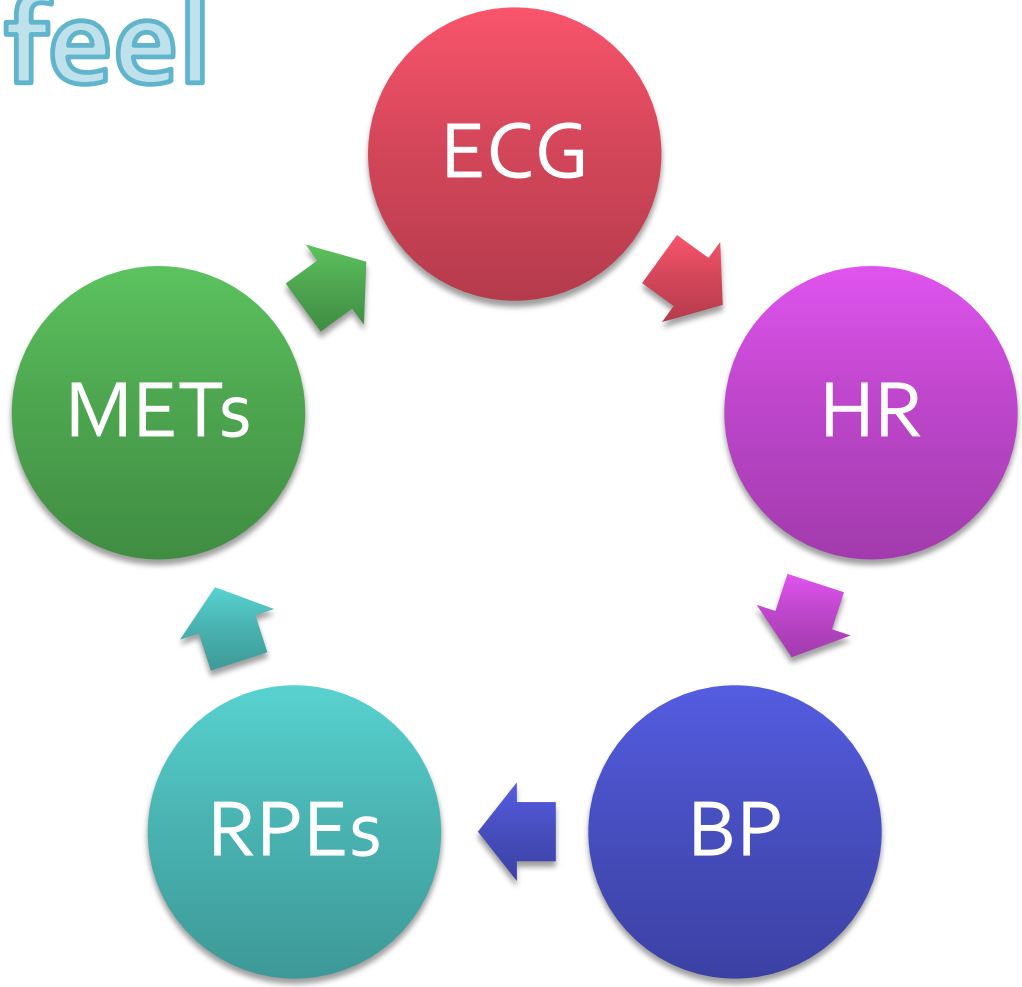
How tired you feel





Some testing laboratories, expired gas analysis permits the assessment of oxygen uptake during the test

Monitoring

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Monitor patient during exercise and recovery

- Patient appearance, ***signs and symptoms of excessive effort and exertional intolerance***; examine for
  - Persistent dyspnea
  - Dizziness or confusion
  - Anginal pain
  - Sever leg claudication
  - Excessive fatigue
  - Pallor, cold sweat
  - Ataxia, incoordination
  - Pulmonary rales

Monitoring

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- Changes in **HR**
  - HR increase linearly as a function of increasing workload and oxygen uptake (**VO2**), plateaus just before maximal oxygen uptake (**VO2max**)
- Changes in **BP**
  - Systolic BP should rise with increasing workloads and VO2; diastolic BP should remain about the same

VO2 and VO2Max

- VO2 (Oxygen Consumption)
  - A measure of the ***volume of oxygen that is used by your body to convert the energy*** from the food you eat into the energy molecules, called adenosine triphosphate (ATP), that your body uses at the cellular level

- VO2Max (Maximal Oxygen Consumption)
  - Simply the ***maximum possible VO2*** that a given person can achieve.

VO2 and VO2max are important in the context of exercise, because they are a ***measure of your body's ability to generate ATP***, and ATP is the energy source that allows your muscles to continue working while you are exercising. Therefore, by definition, a VO2max measurement is ultimately a ***measure of your cardiorespiratory fitness level.***

Monitoring

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- **Rating of perceived exertion (RPE)**
  - Original Borg scale : rates exercise intensity using numbers from **6 to 20**, with descriptors from very, very light to very, very hard
  - RPE increases linearly with increasing exercise intensity and correlates closely to VO_2 max and heart rate.
  - An important measure for individuals who do not exhibit the typical rise in HR with exercise

Borg RPE scale

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Rating of Perceived Exertion Borg RPE Scale		
6 7 8 9 10 11	Very, very light Very light Fairly light	How you feel when lying in bed or sitting in a chair relaxed. Little or no effort.
12 13 14 15 16	Somewhat hard Hard	Target range: How you should feel with exercise or activity.
17 18 19 20	Very hard Very, very hard Maximum exertion	How you felt with the hardest work you have ever done. Don't work this hard!

http://www.ivyrehab.com/wp-content/uploads/2013/10/Borg-scale-1.png

Monitoring

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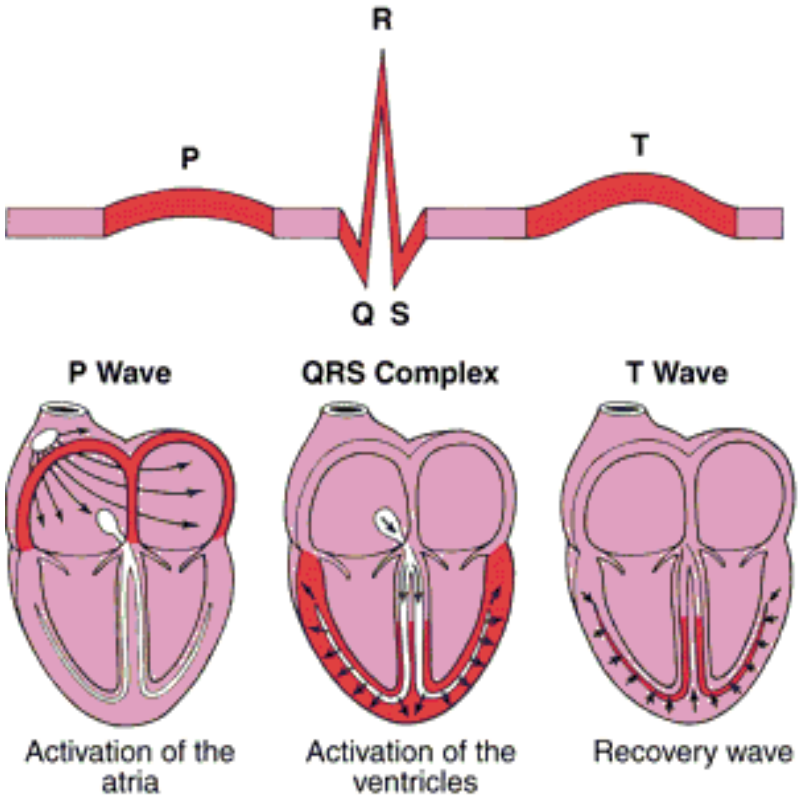
- **ECG** (Electrocardiogram)
  - 3 distinct waves are produced during cardiac cycle
  - **P wave** caused by arterial depolarization
  - **QRS complex** caused by ventricular depolarization
  - **T wave** results from ventricular repolarization



http://qsota.com/wp-content/uploads/2015/03/Electrocardiogram-a-survey.gif

ECG Paper

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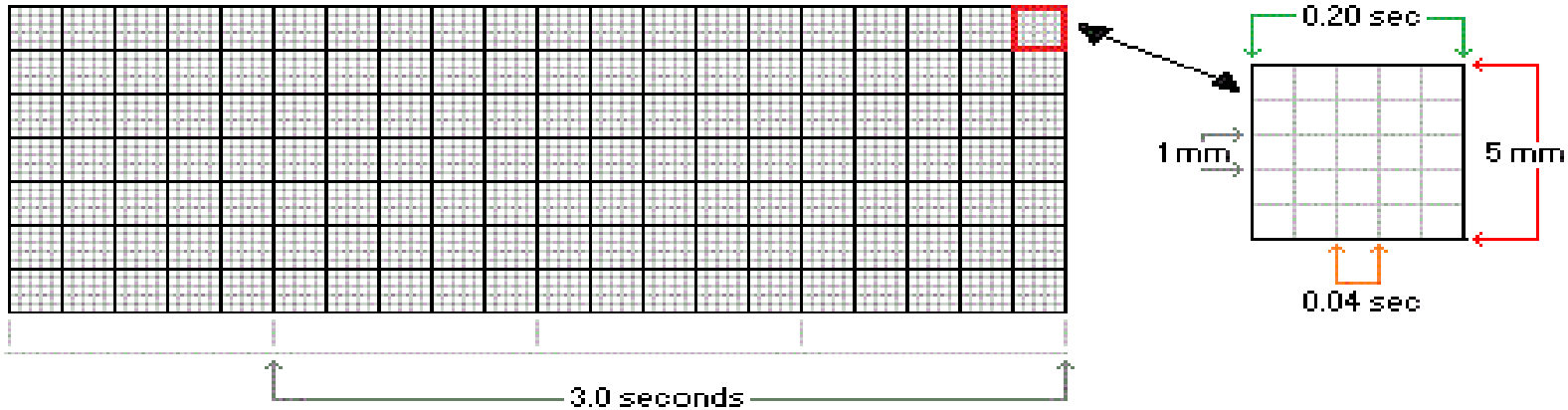
- Small box
  - 1 mm
  - 0.04 s
- Large box
  - 5 mm (0.5mV)
  - 0.20 s



http://www.ambulancetechnicianstudy.co.uk/images/ecg_paper1.gif

ECG Paper

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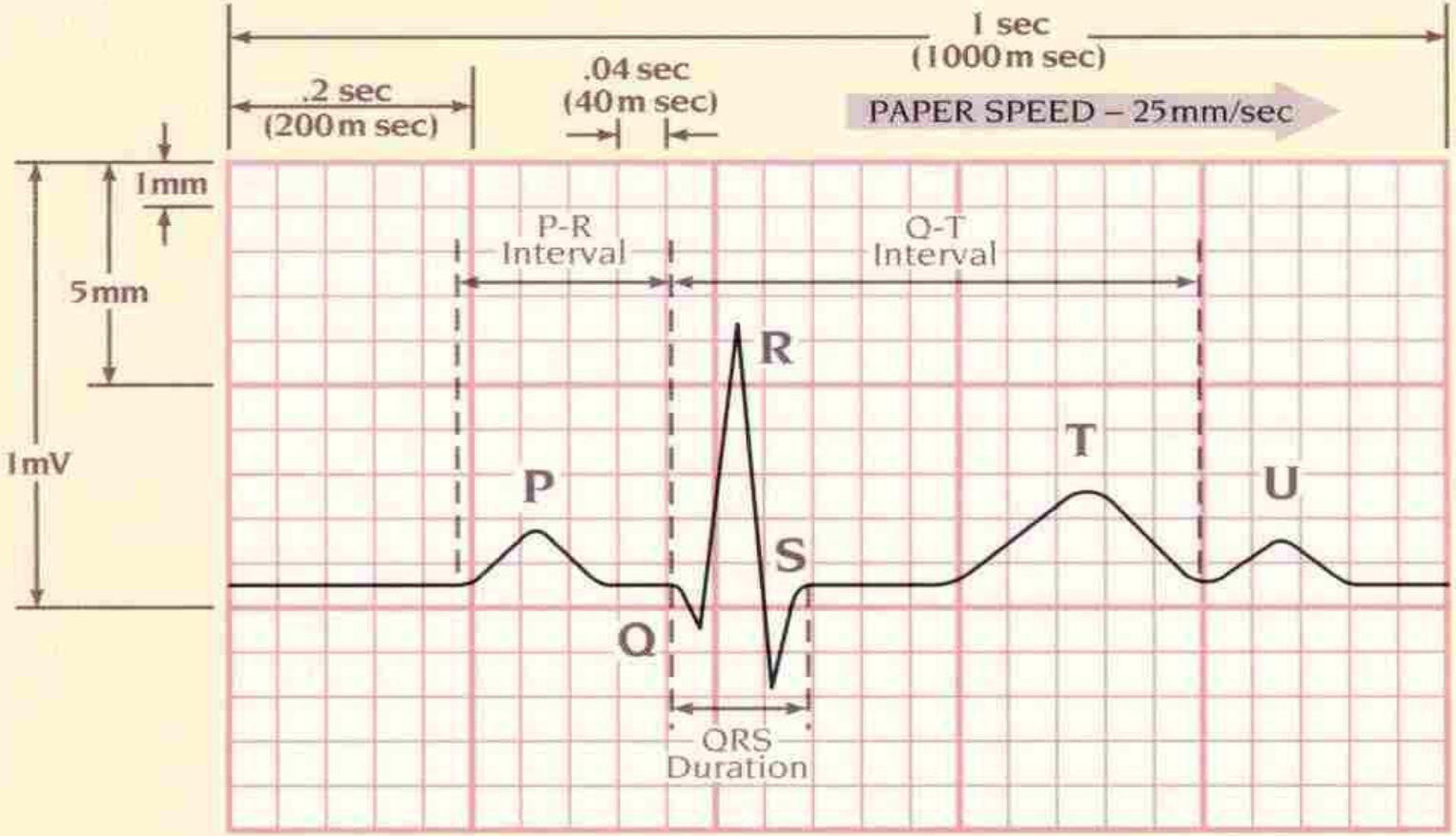


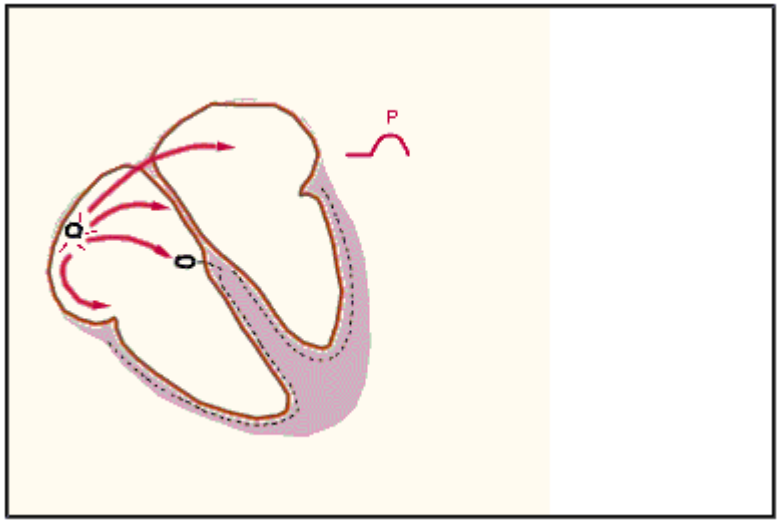
VERTICAL AXIS	1 Small Square	=	1mm (0.1mV)
	1 Large Square	=	5mm (0.5mV)
	2 Large Squares	=	1mV

HORIZONTAL AXIS	1 Small Square	=	.04 sec (40 m sec)
	1 Large Square	=	.2 sec (200 m sec)
	5 Large Squares	=	1 sec (1000 m sec)

http://pds.egloos.com/pds/1/200506/29/05/b0053005_16212451.jpg

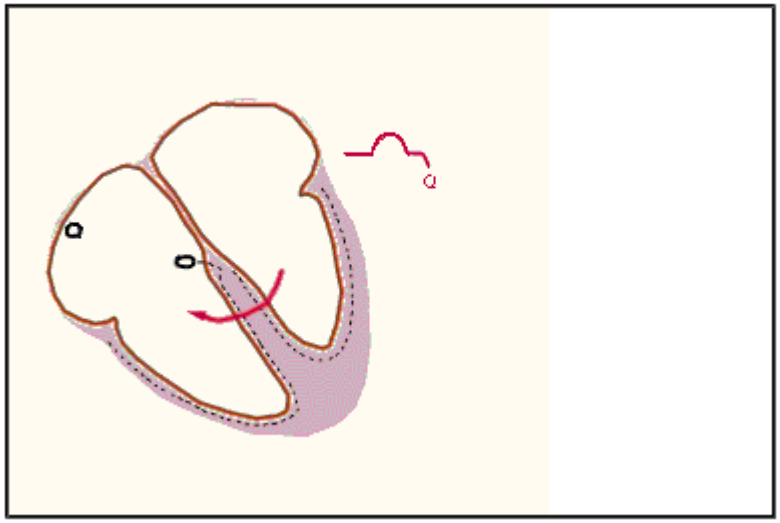
Activation of the Heart and the ECG

- The electrical activity of the heart originates in the **SA node**.
- The impulse then rapidly spreads through the right atrium to the **AV node.**
- It also spreads through the **atrial muscle** directly from the right atrium to the left atrium.
- The P-wave is generated by activation of the muscle of both atria



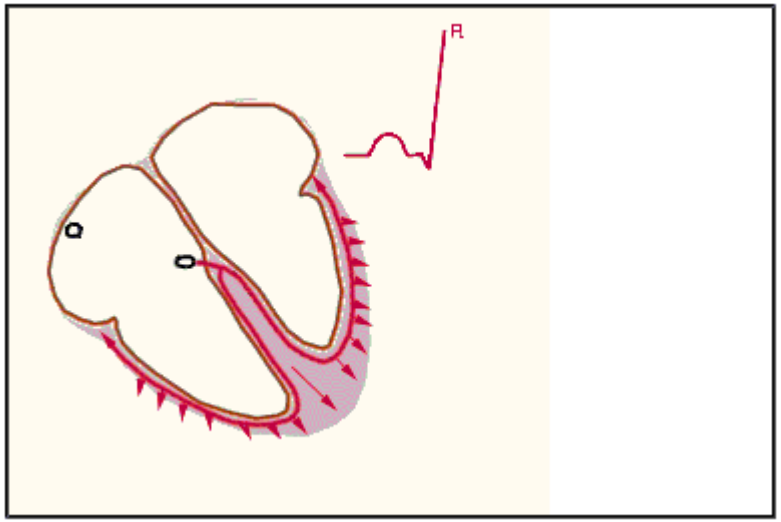
Activation of the Heart and the ECG

- The impulse travels very slowly through the **AV node**, then very quickly through the **bundle of His**, then the **bundle branches**, the **Purkinje** network, and finally the **ventricular muscle**.
- The first area of the ventricular muscle to be activated is the interventricular septum, which activates from left to right.
- This generates the Q-wave.



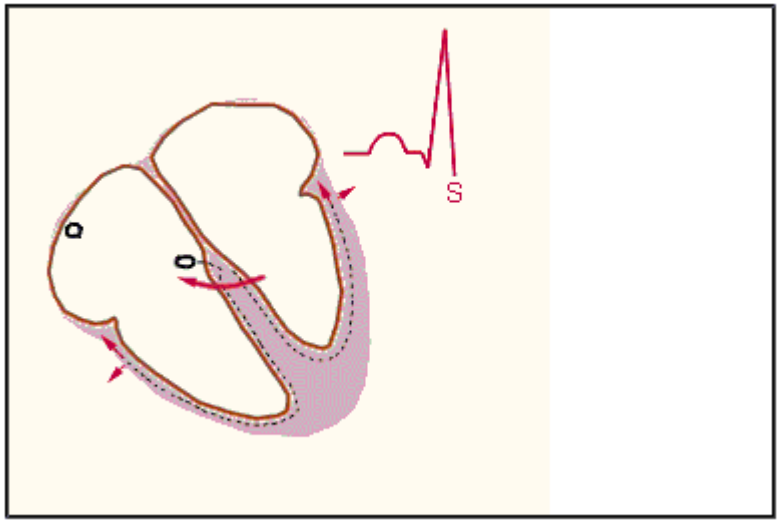
Activation of the Heart and the ECG

- Next, the left and right ventricular free walls, which form **the bulk of the muscle of both ventricles**, gets activated, with the endocardial surface being activated before the epicardial surface.
- This generates the R-wave.



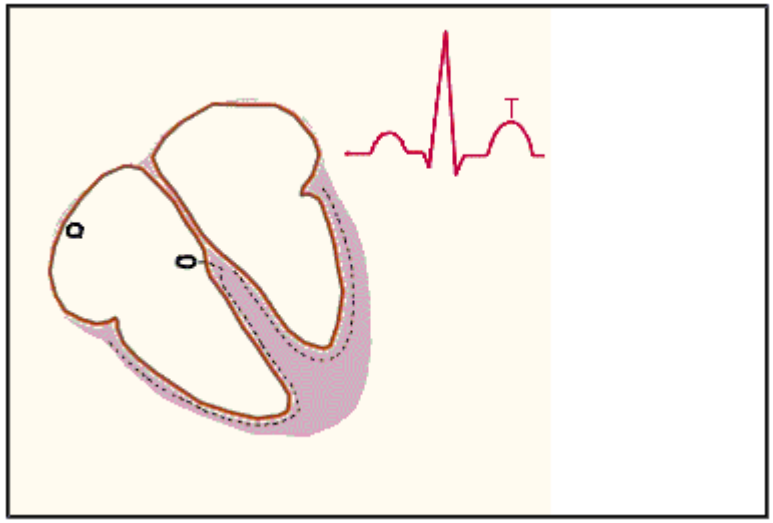
Activation of the Heart and the ECG

- A few small areas of the ventricles are activated at a rather late stage.
- This generates the S-wave.



Activation of the Heart and the ECG

- Finally, the **ventricular muscle repolarizes.**
- This generates the T-wave.



Electrocardiogram (ECG)

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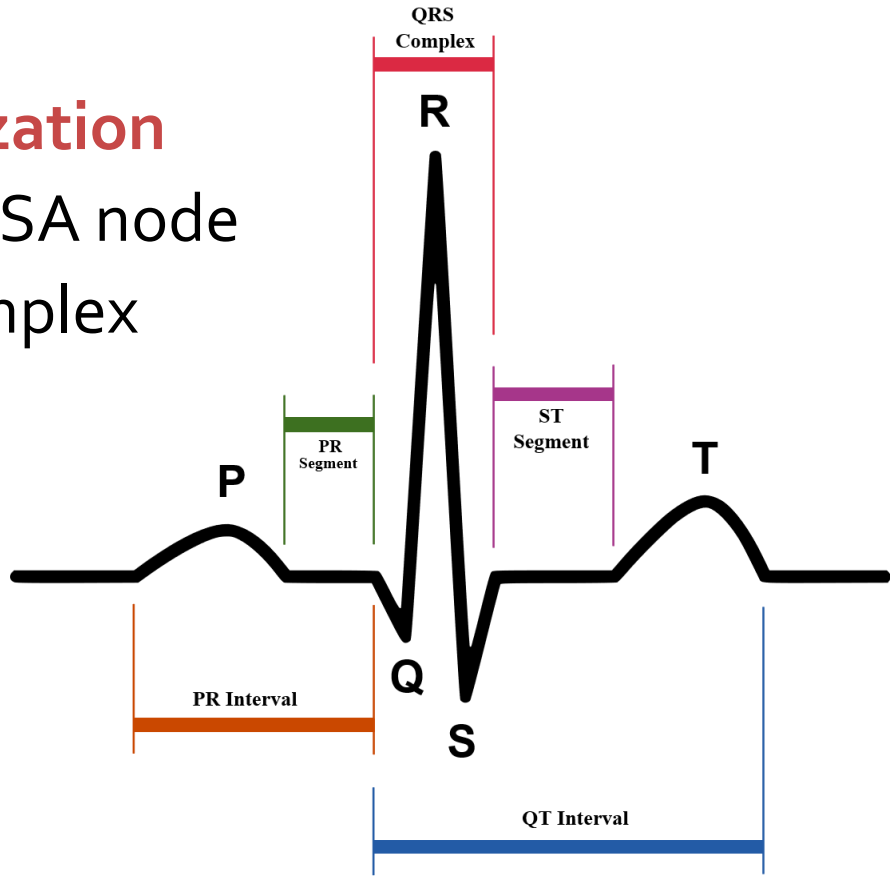
- **P wave**
  - Represents **atrial depolarization**
  - Impulse normally from the SA node
  - Occurs before the QRS complex
  - Shape
    - Generally rounded
  - Duration
    - 0.06-0.11 s
  - Amplitude
    - Usually < 0.3 mV (< 3mm)
  - ***Focused on location and shape***



http://a-fib.com/wp-content/uploads/2012/08/Schematic-diagram-of-normal-sinus-rhythm-for-a-human-heart-as-seen-on-ECG-Wikipedia-free-to-use-1015x1024.png

Electrocardiogram (ECG)

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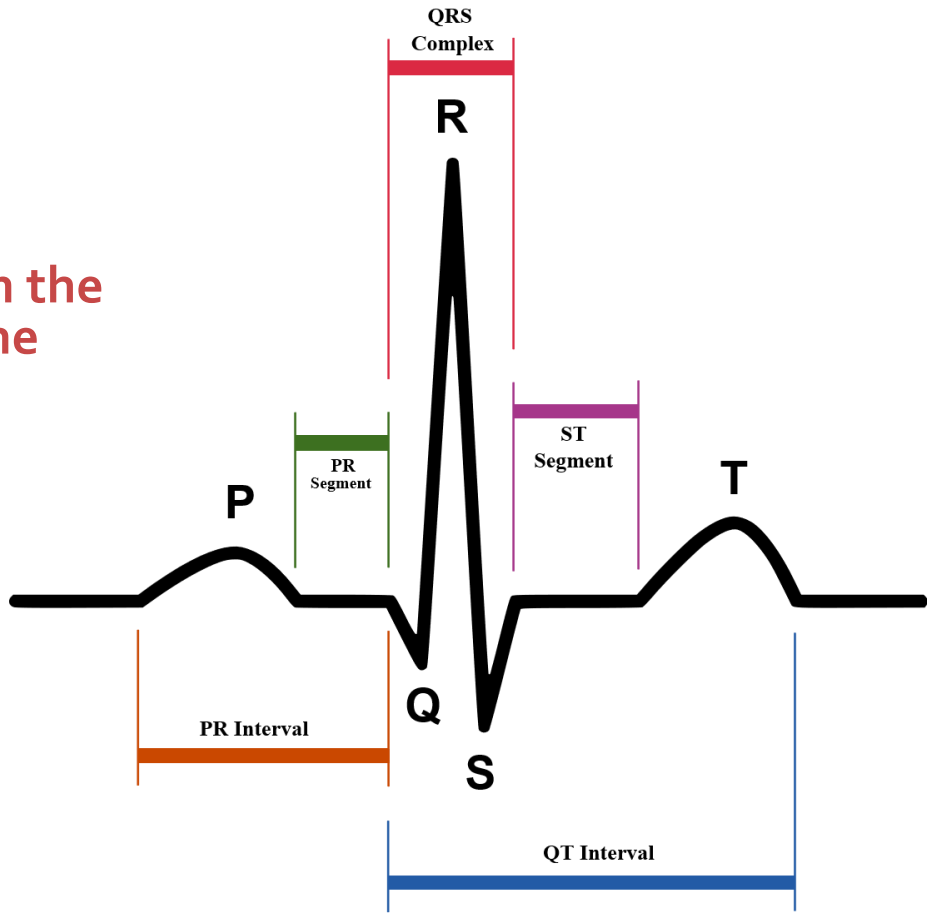
- **P-R Interval**
  - Shape
    - P wave and isoelectric (flat)
    - Represents time it takes for the electrical **impulse to travel from the SA node through AV node to the bundle branches**
  - Duration
    - 0.12-0.2 s
    - Shorter PR indicates impulse didn't originate in SA node
    - Prolonged PR indicated the Impulse is delayed as it passes through the AV node (AV-block)
  - ***Focus on duration***



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Electrocardiogram (ECG)

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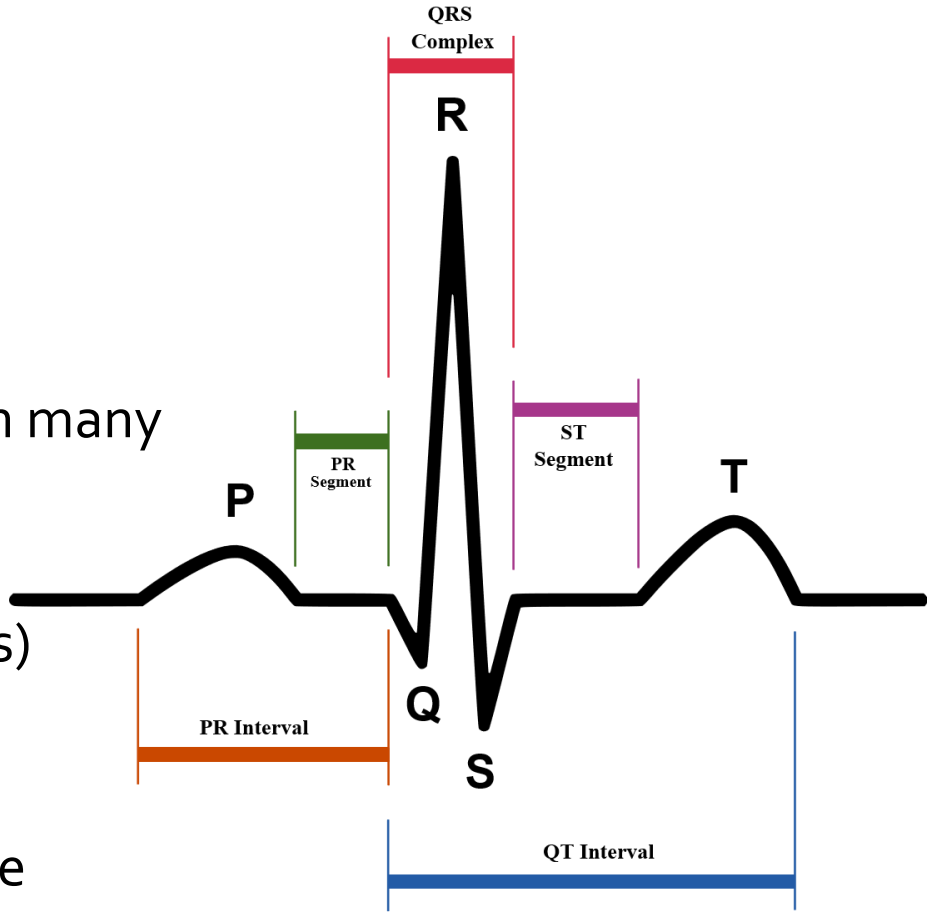
- **QRS complex**
  - Ventricular depolarization
  - Atrial repolarization
  - Shape
    - The QRS complex can take on many shapes in various ECG leads
  - Duration
    - 0.6-0.10 s (1.5-2.5 small boxes)
  - Amplitude
    - <30mm (3mV)
      – peak R-wave to peak S-wave
  - ***Focus on shape and duration***



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Electrocardiogram (ECG)

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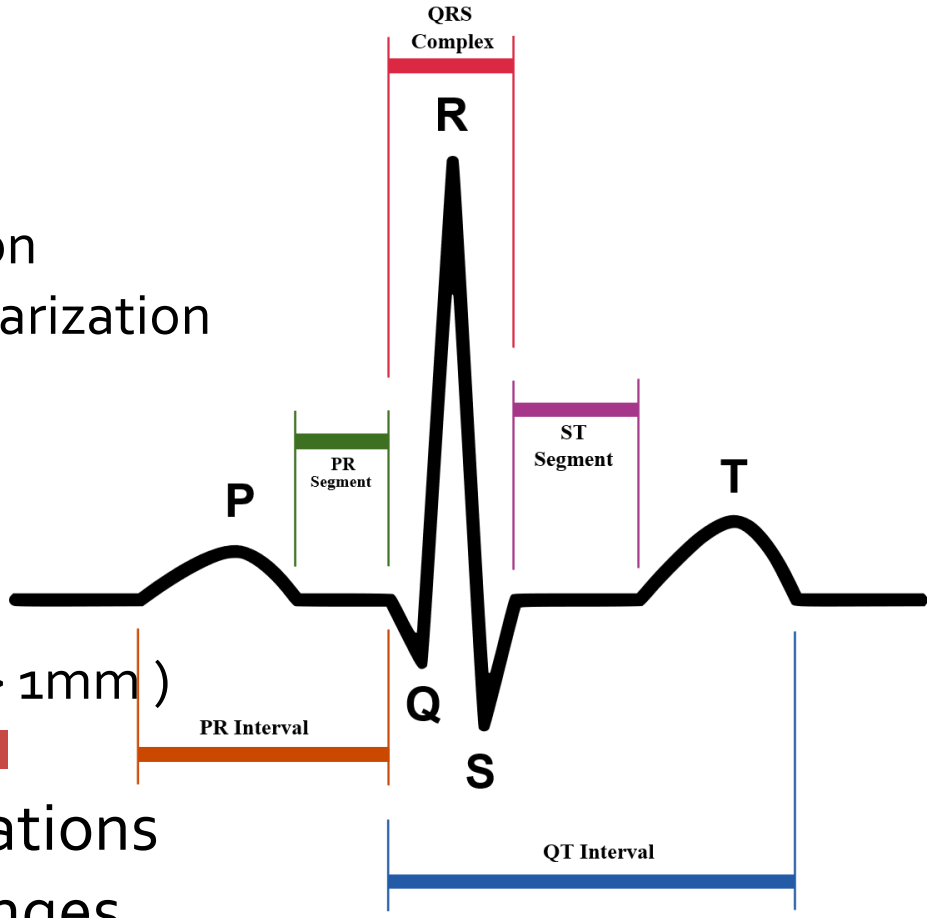
- **S-T segment**
  - S-T segment represents
    - End of ventricular depolarization & beginning of ventricular repolarization
    - **Lowest blood supply through coronary arteries**
  - Shape
    - Flat
    - Depression -> **MI** or ischemia (> 1mm)
    - Elevation more than 1mm -> **MI**
  - Some conditions and medications may cause S-T segment changes



http://a-fib.com/wp-content/uploads/2012/08/Schematic-diagram-of-normal-sinus-rhythm-for-a-human-heart-as-seen-on-ECG-Wikipedia-free-to-use-1015x1024.png

Electrocardiogram (ECG)

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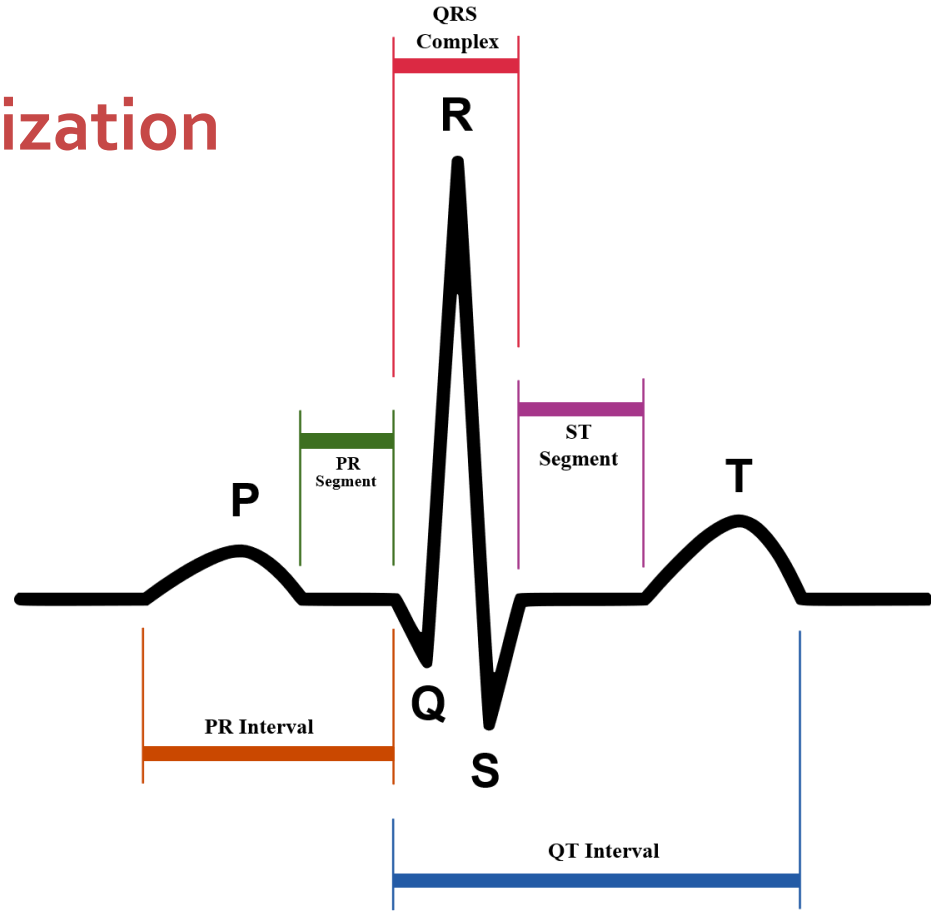
- T wave
  - Ventricular repolarization



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Electrocardiogram (ECG)

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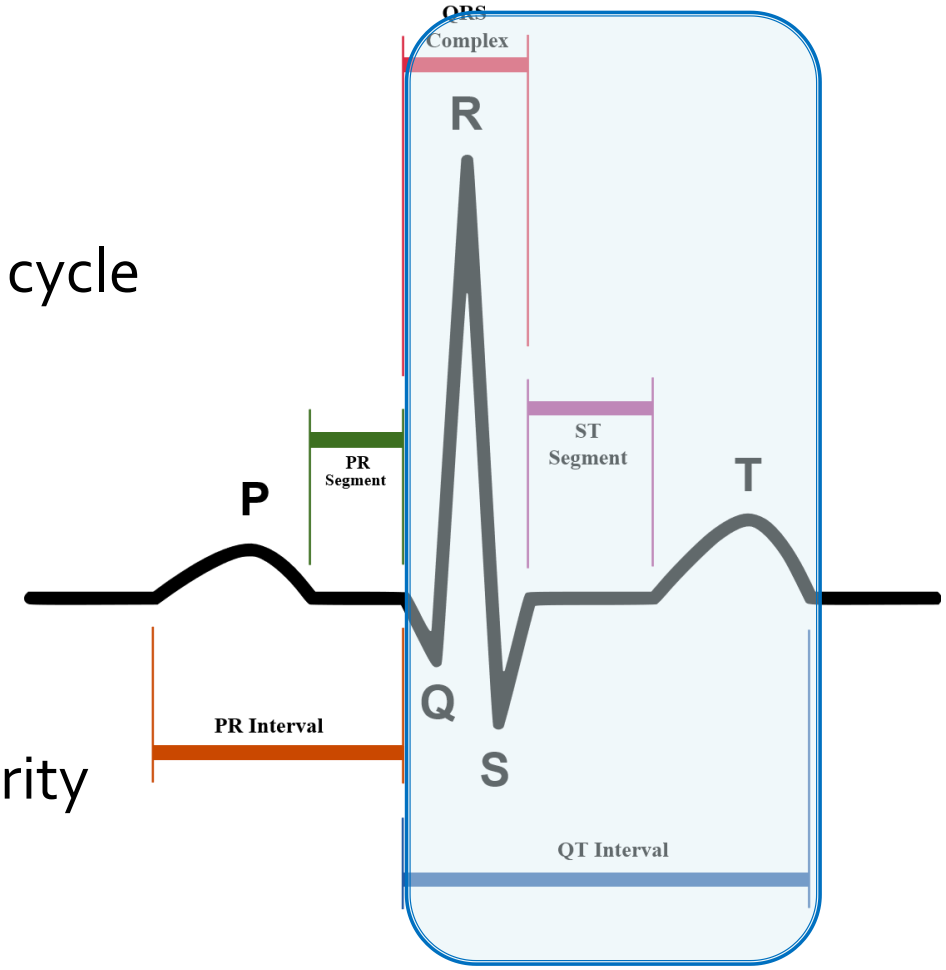
- **Q-T interval**
  - Time needed for ventricular depolarization-repolarization cycle
  - Interval time varies with:
    - Age/sex/HR
    - QT shortens with increased HR
    - Usually between 0.36 – 0.44 s
  - Abnormal duration may indicate a myocardial irregularity
  - ***Focus on duration***



http://a-fib.com/wp-content/uploads/2012/08/Schematic-diagram-of-normal-sinus-rhythm-for-a-human-heart-as-seen-on-ECG-Wikipedia-free-to-use-1015x1024.png

Normal Sinus Rhythm (NSR)

- Sinus rhythm
  - Virtually all beats arise from the sinus node
- Sinus P wave
- P wave is conducted normally through the AV junction
- With 'normal' sinus rhythm heart rate (atrial and ventricular) is regular and falls within the range of 60-100bpm.

Normal sinus rhythm on ECG

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www.khanacademy.org

Electrocardiogram (ECG)

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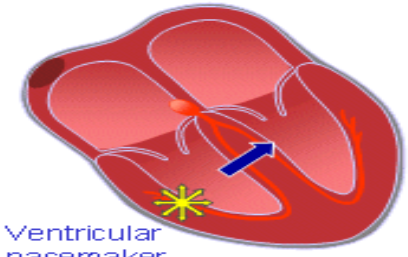
- ECG changes with exercise : **healthy individual**
  - **Tachycardia** : heart rate increase is directly proportional to exercise intensity and myocardial work
  - Rate-related shortening of QT interval
  - S-T segment depression, upsloping, ***less than 1mm***
  - Exertional arrhythmias: rare, single **PVCs**

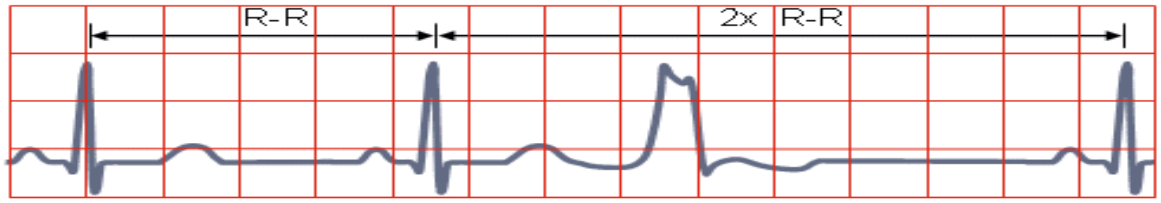
Premature Ventricular Contrition

- Premature **heartbeats originating from the ventricles** of the heart.
- A sign of **decreased oxygenation** to the heart muscle.
- PVCs are benign and may even be found in healthy hearts.
- A PVC may be perceived as a "skipped beat" or felt as palpitations in the chest.
- Although there are many signs and symptoms associated with PVCs, PVCs may have **no symptom** at all.
- PVCs can occur in a healthy person of any age, but are more prevalent in the **elderly and in men.**

PREMATURE VENTRICULAR CONTRACTION

A single impulse originates at right ventricle





Time interval between normal R peaks is a multiple of R-R interval

http://www.bem.fi/book/19/fi/1903a.gif

Electrocardiogram (ECG)

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- ECG changes with exercise : an individual with myocardial ischemia and CAD
  - **Significant tachycardia** : occurs at lower intensities of exercise
  - **Exertional arrhythmias** : increased frequency of ventricular arrhythmias during exercise and/or recovery
  - S-T segment depression; horizontal or downsloping depression, ***greater than 1mm*** below baseline is indicative of myocardial ischemia

Monitoring

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- Determine activity levels :**METs** (Metabolic equivalents)
  - MET : the amount of oxygen consumed at rest (sitting); equal to 3.5mL/kg per minute.
  - MET levels can be estimated during ETT during steady state exercise; the max VO2 achieved on ETT is divided by resting VO2; highly predictable with standardized testing modes.

$$\text{Estimated MET} = \frac{VO2\ max}{resting\ VO2}$$

  - Can be used to predict energy expenditure during certain activities.

Metabolic Equivalent (MET)

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Metabolic Equivalent (MET) Activity Chart

INTENSITY (70-KG PERSON)	ENDURANCE PROMOTING	ACTIVITY
1.5–2 METs	Too low in energy level	Standing, walking slowly (1 mph)
2–3 METs	Too low in energy level, unless capacity is very low	Level walking (2 mph), level bicycling (5 mph)
3–4 METS	Yes, if continuous and if target heart rate reached	Level walking (3 mph), bicycling (6 mph)
4–5 METs	Recreational activities must be continuous, lasting longer than 2 minutes	Walking (3½ mph), bicycling (8 mph)
5–6 METs	Yes	Walking at brisk pace (4 mph), bicycling (10 mph)
6–7 METs	Yes	Walking at very brisk pace (5 mph), bicycling (11 mph), swimming leisurely (20 yd/min)
7–8 METs	Yes	Jogging (5 mph), bicycling (12 mph)
8–9 METs	Yes	Running (5.5 mph), bicycling (13 mph), swimming (30 yd/min)
>10 METs	Yes	Running 6 mph = 10 METs, 7 mph = 11.5 METs, 8 mph = 13.5 METs, 9 mph = 15 METs, 10 mph = 17 METs; swimming moderate/hard (>40 yd/min)

Adapted from: Fox, Naughton, Gorman. Mod Concepts Cardiovas Dis 1972, 4:25. American Heart Association.

Metabolic Equivalent (MET)

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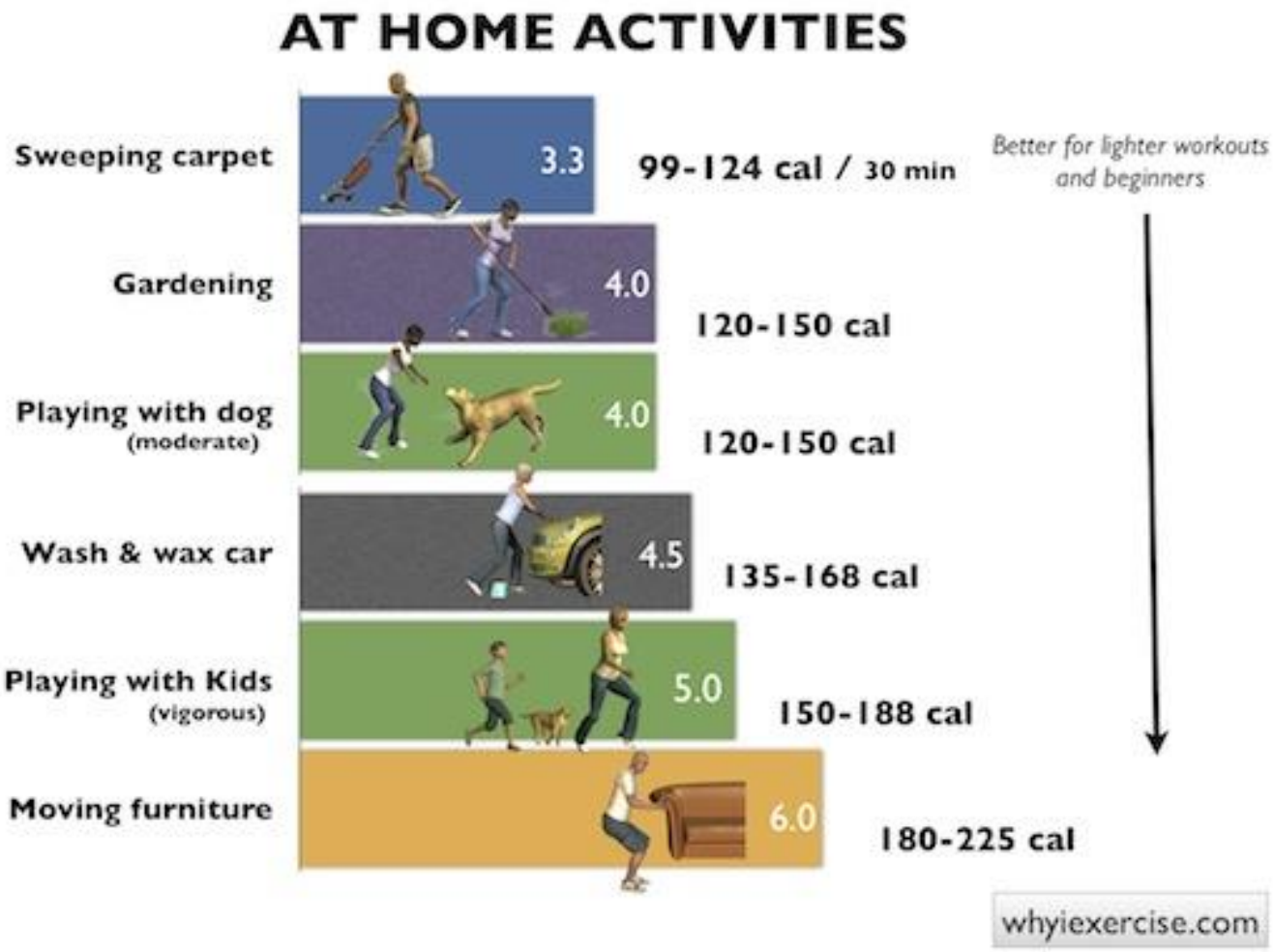

Metabolic Equivalent (MET)

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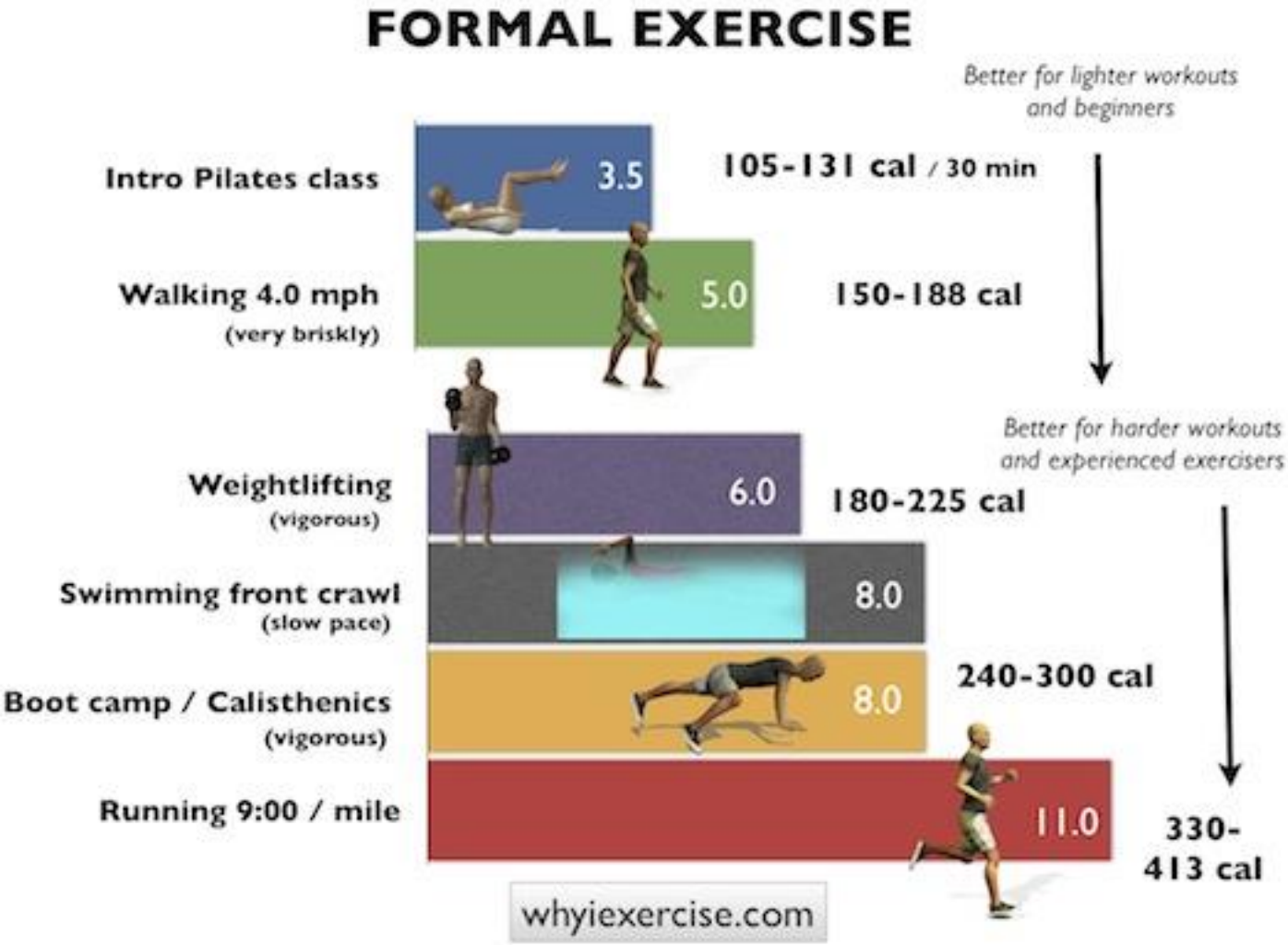

Metabolic Equivalent (MET)

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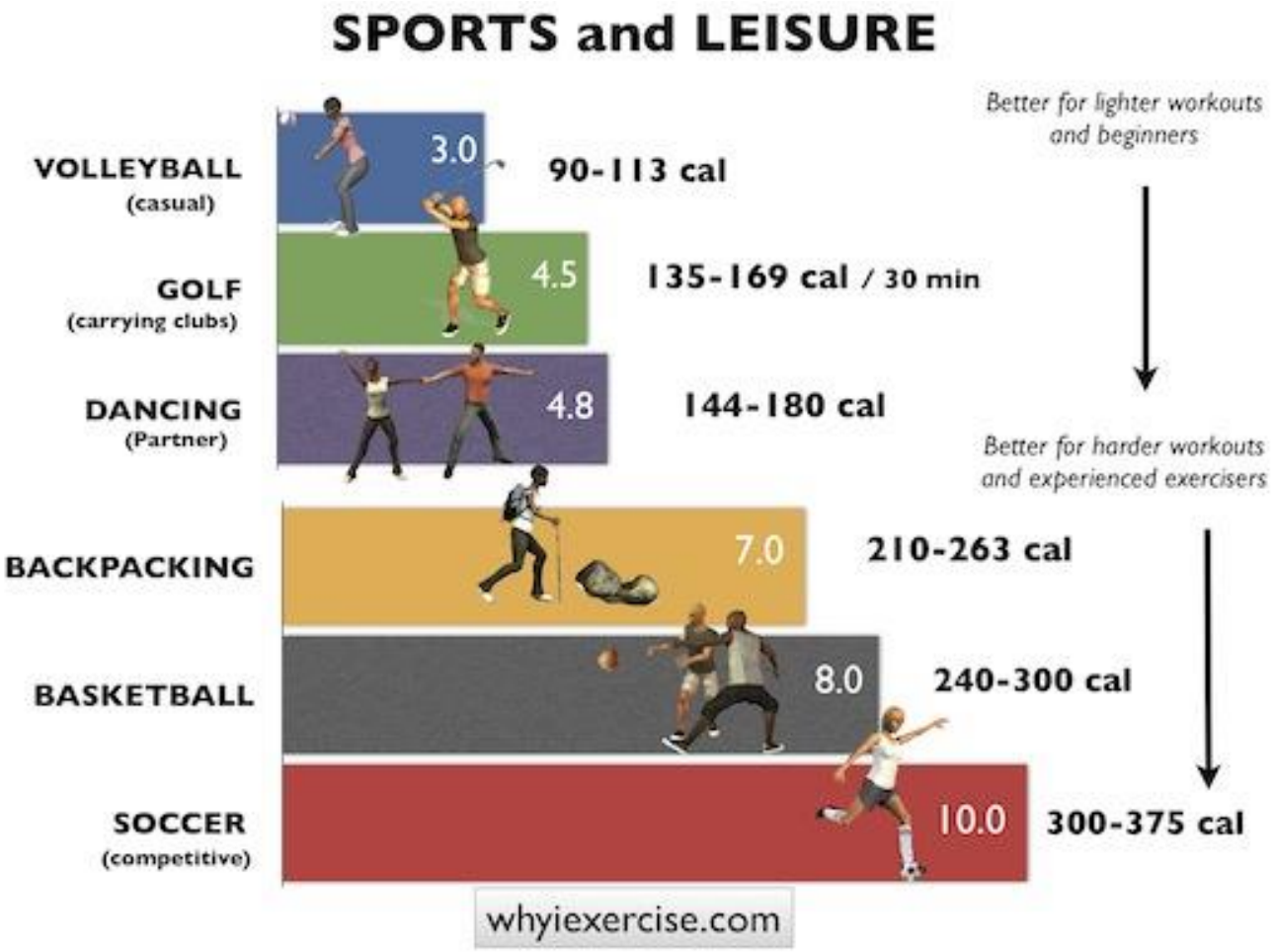

Basic ETT Protocol

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- Pre-test
  - 12-lead ECG and BP in exercise postures
- Exercise
  - 12-lead ECG recorded during last 15 seconds of every stage (2-3minutes) and at peak exercise or continuously
  - BP during last minute of each stage
  - RPE at the end of each stage

Basic ETT Protocol

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- Post-test
  - 12-lead ECG and BP immediately after exercise and every 1-2 minutes until stabilized near baseline
  - Symptomatic ratings taken until return to baseline
- Monitoring continues until :
  - SBP is within 20 mmHg of resting rate
  - Arrhythmias have stabilized
  - ST segment depression/elevation is <1mm difference from baseline levels

Safety in ETT

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- The physical therapist must have a clear understanding of the rationale **for terminating any exercise test**

Criteria for Termination of Maximal and Low-Level/Submaximal Testing

Criteria for Termination of Maximal Testing

Increasing frequency or pairing of premature ventricular complexes
Development of ventricular tachycardia
Rapid atrial arrhythmias, including atrial fibrillation or atrial flutter, with uncontrolled ventricular response rates
Development of second- or third-degree heart block
Increased angina pain (Level 2 on a scale of 4)
Hypotensive blood pressure response (20 mm Hg or greater decrease)
Extreme shortness of breath
Dizziness, mental confusion, or lack of coordination
Severe ST-segment depression. The American College of Sports Medicine recommends termination when the ST segment is depressed 2.0 mm or more, although some testing personnel may proceed when changes of greater magnitude are demonstrated as long as there is no evidence of other abnormal responses.[100]
Observation of the patient reveals pale and clammy skin (pallor and diaphoresis)
Extremely elevated systolic or diastolic blood pressure, or both, which may or may not be associated with symptoms.
On achievement of predicted maximal heart rate; it is usually safe to proceed with the test beyond the predicted maximal heart rate if the patient is able and willing to continue and if other indications to terminate the test are absent.[106]
Presence of leg fatigue or leg cramps or claudication pain
Patient request for termination of test

Criteria for Termination of Low Level/ Submaximal Testing

An oxygen consumption level of 17.5 mL of oxygen per kg (6 METs) achieved
70% to 75% of age-predicted maximal heart rate achieved
Fatigue or dyspnea
Maximal heart rate of 120 to 130 beats per minute
Frequent (nine or more per minute) unifocal or multifocal premature ventricular contractions, paired premature ventricular contractions, or ventricular tachycardia
ST-segment depression of 1.0 to 2.0 mm
Claudication pain
Dizziness
Decrease in systolic blood pressure of 10 to 15 mm Hg below peak value
Hypertensive blood pressure (systolic >200 mm Hg, diastolic >110 mm Hg)
Level 1 (out of 4) angina

Essentials of Cardiopulmonary Physical Therapy, 3rd edition, Ellen Hillegass, Elsevier

Interpretation of Results

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- Once the test is concluded, the results are written on a **worksheet** (documented)to provide data for the interpretation.
- The final summary of ETT should define weather the outcome of the test is **normal or abnormal**.
- If the outcome is abnormal, the summary should provide the **reasons.**
- The interpretation also provides valuable information regarding **safety** during exercise for the patient.

Interpretation of Results

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Name John Doe Date

Age 45 Sex M Height 5'10" Weight 190 lb.

Diagnosis Reason for test chest pains

Protocol Bruce

Time of test 8 AM Time last cigarette Time last meal 12

Medications None Time last dose

Physician

RESULTS

12-Lead ECG interpretation Normal

Minutes completed 7.06 Limiting factor(s) Leg fatigue

Rest HR 84 Rest BP 140/98 Heart sounds Normal

Maximum HR 170 Maximum BP 190/102

BP Response Diastolic hypertension throughout

Chest pain None

Summary of ST segment changes Negative for ischemia

Summary of arrhythmias Rare PAC throughout

Physical work capacity Poor, 30% below predicted functional aerobic impairment

Remarks/recommendations Patient needs an exercise program to decrease blood pressure and improve functional aerobic impairment.

Interpreted by Date

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2-minute Step Test

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1. Take resting vital signs
2. Have patient/client stand **next to a wall**. Measure the height of the **iliac crest and patella** and mark it on the wall. Then place a piece of tape on the wall **half the distance between the two**.
3. On the signal "go" the patient/client begins stepping (not running) in place, **raising each knee to the mark on the wall**, for as many times as possible in the **2 minute** period.
4. Only count the number of times the **right knee** reaches the required height. That is the score.
5. If the proper knee height cannot be maintained, ask the participant to slow down, or to stop until they can regain the proper form, but keep the stopwatch running.
6. At the end of the test, provide a cool down by asking the patient/client to walk slowly for a minute.
7. A person with **impaired balance may use the back of a chair** as a touch-hold for stability. Note this modification in **your documentation**
8. Take post exercise vital signs.

2-minute Step Test

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https://nationalvetcontent.edu.au/alfresco/d/d/workspace/SpacesStore/efcaa5b0-1c5b-40f7-bd55-64a59158f7cf/805/fit_tb/fito11_1_lr10/fito11_1_lr10res/fito11_1_lr10_1_4_1.jpg

2-minute Step Test

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Range of scores between the 25% and 75% percentiles		
Age	Number of steps – Women	Number of steps – Men
60 - 64	75-107	87-115
65 - 79	73-107	86-116
70 - 74	68-101	80-110
75 - 79	68-100	73-109
80 - 84	60-90	71-103
85 - 90	55-85	59-91
90 - 95	44-72	52-86

Scores *less than 65* were associated with **lower levels** of functional ability

Rikli RE, Jones CJ (1999). Functional fitness normative scores for community residing older adults ages 60-94. Journal of Aging and Physical Activity, 7, 160-179.

6-minute walk Test

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- The original purpose of the six minute walk was to test **exercise tolerance in chronic respiratory disease and heart failure.**
- The 6-Minute Walk test is a **sub maximal measure of aerobic capacity**. The person may use an ambulation aid and oxygen if they do so normally
- The test has since been used as a performance-based measure of **functional exercise capacity** in other populations including healthy older adults, people undergoing knee or hip arthroplasty, fibromyalgia, and scleroderma. It has also been used with children.

6-minute walk Test

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- **Instructions to the Participant**

"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." (ATS, 2002) We will avoid having a conversation so that you can save your wind for walking. You can begin when I say **'go'.**

6-minute walk Test

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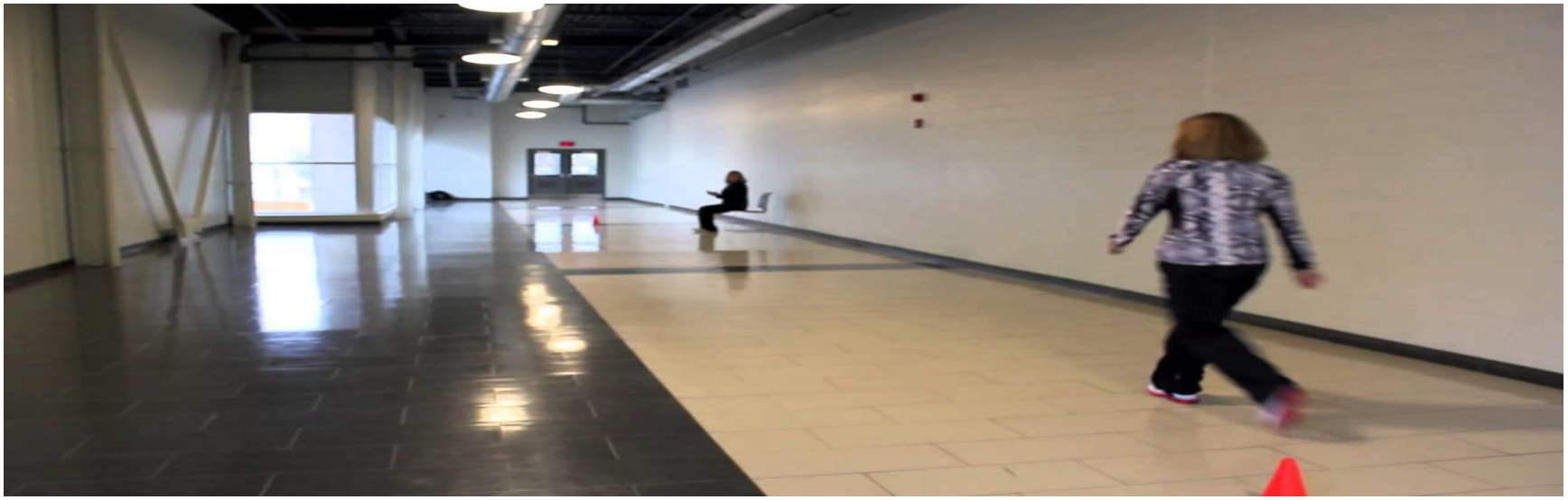

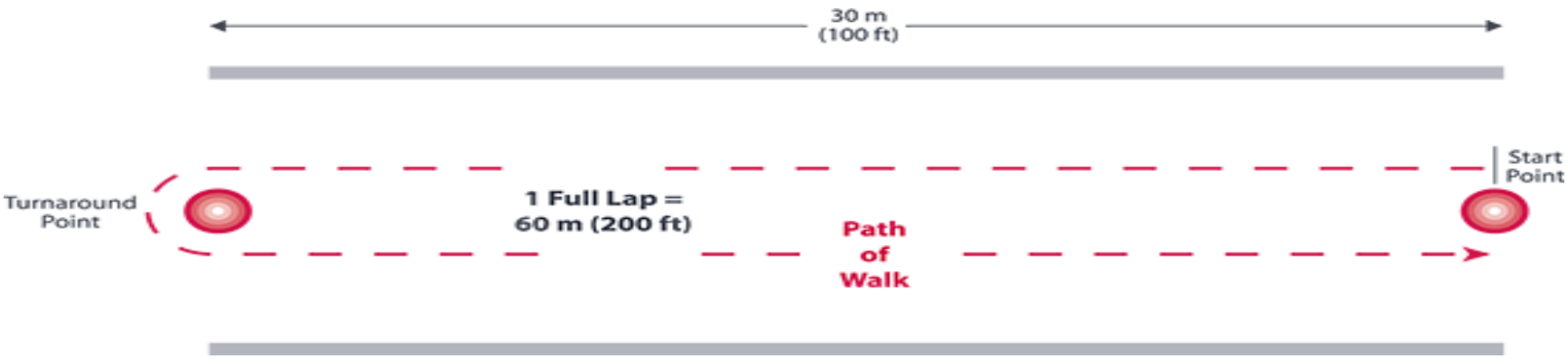

https://www.insightsonpah.com/Living_with_PAH/Quality_of_Life/images/walk.gif

6-minute walk Test

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6 minute walk test : Normal Reference value

Men

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

Subtract 150 to get Lower limit of Normal

Women

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

Subtract 140 to get Lower limit of Normal

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

www.drsvenkatesan.co.in

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