Recovery from Physical Activity

The cardiorespiratory response and mobile health use cases

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Overview

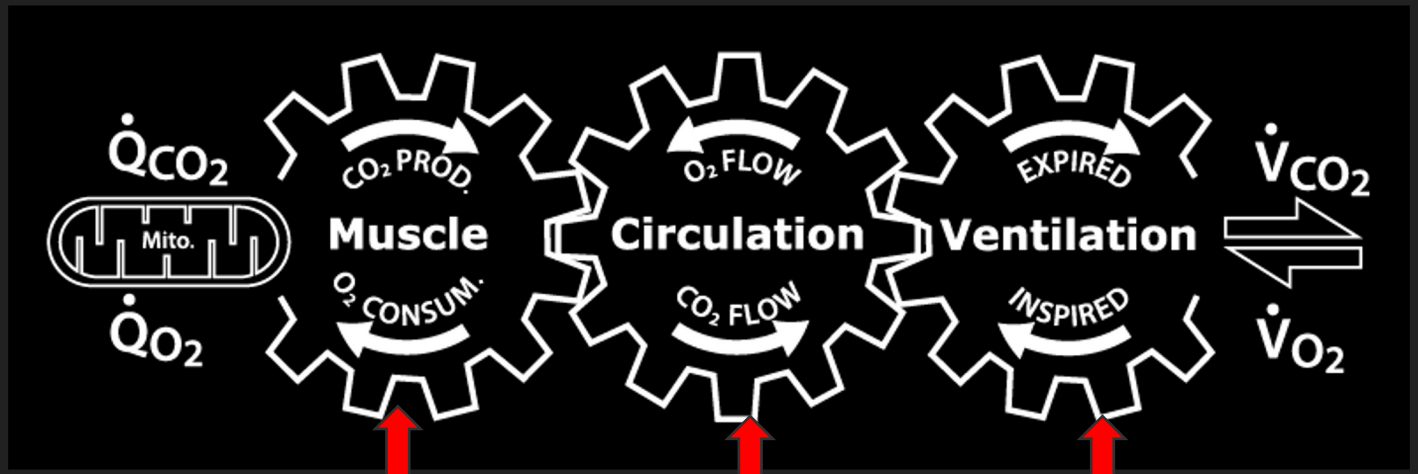
1. What happens during physical activity?
2. What happens during recovery from physical activity?
3. What are we capturing with mobile health?

Variables of interest:

- Hemodynamics (Q, BP, HR, TPR)
- Respiratory (Respiration Rate, Tidal Volume, Ventilation)
- Gas Exchange (VO2, VCO2)
- Heart Rate Variability (HRV)
- Symptoms (Rating of Perceived Exertion, Dyspnea, Angina)

What happens before recovery?

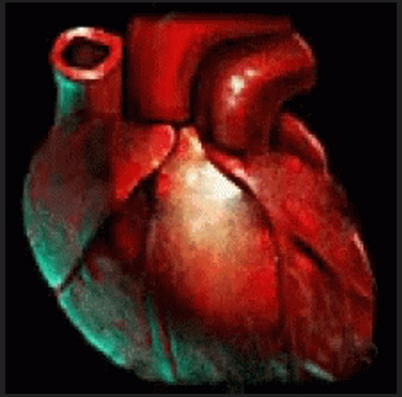
Rest >> **Physical Activity** >> Recovery

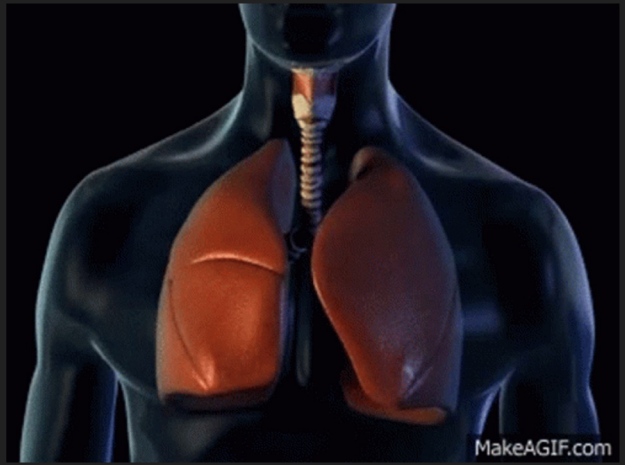


- Obesity
- Detraining

- CAD
- Heart failure

- Restrictive / Obstructive Pulmonary diseases

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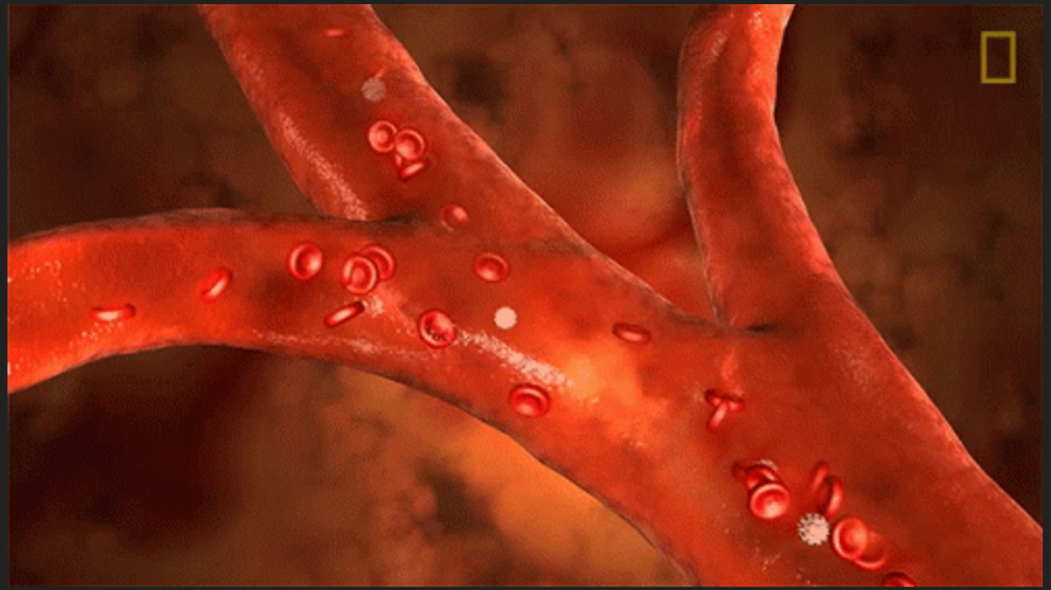
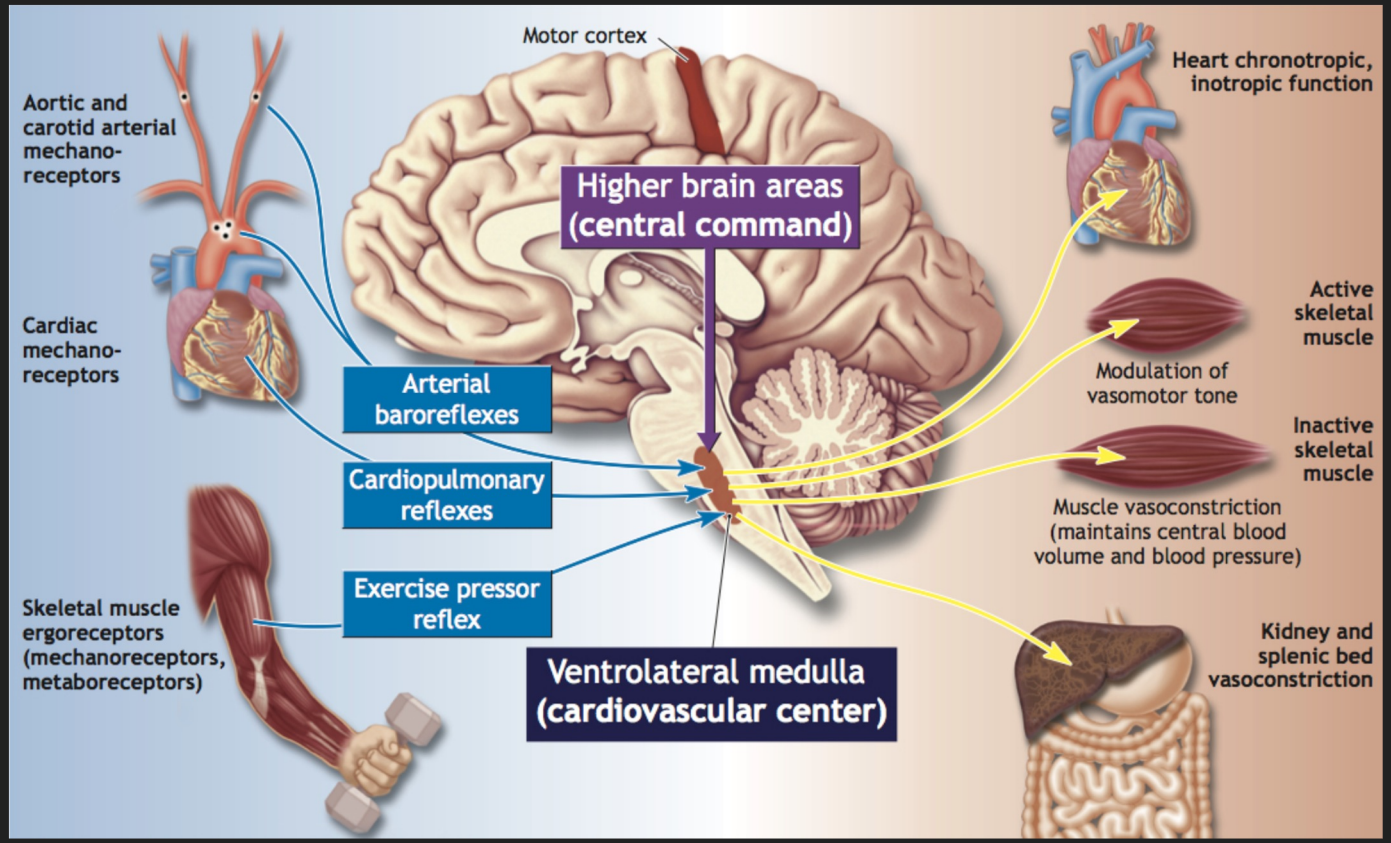


Responses to Physical Activity

Cardiovascular Physiology

Extrinsic regulation of heart rate and circulation



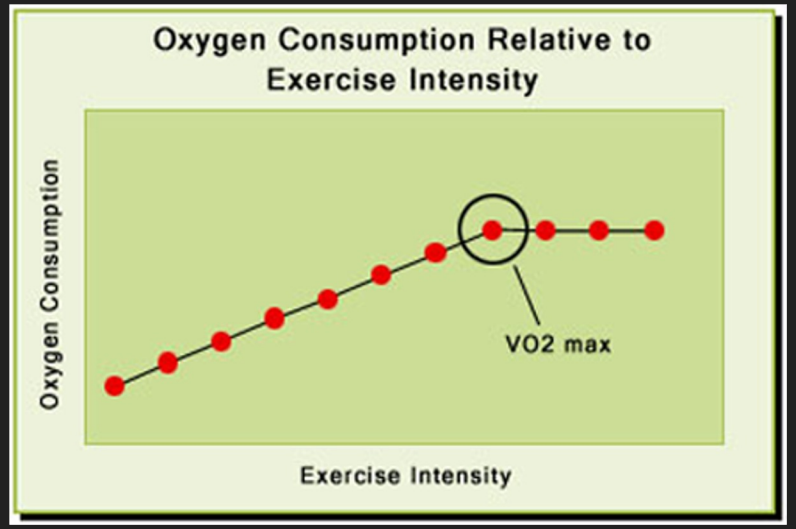
Oxygen Consumption

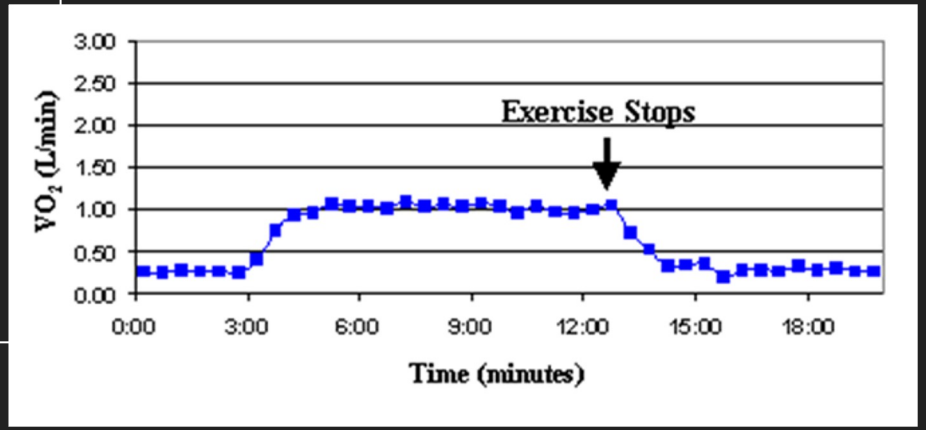
- Increased O_2 demand with exercise (primarily from working muscles)

  VO_2 = Cardiac Output (Q) x a-vO_2 difference

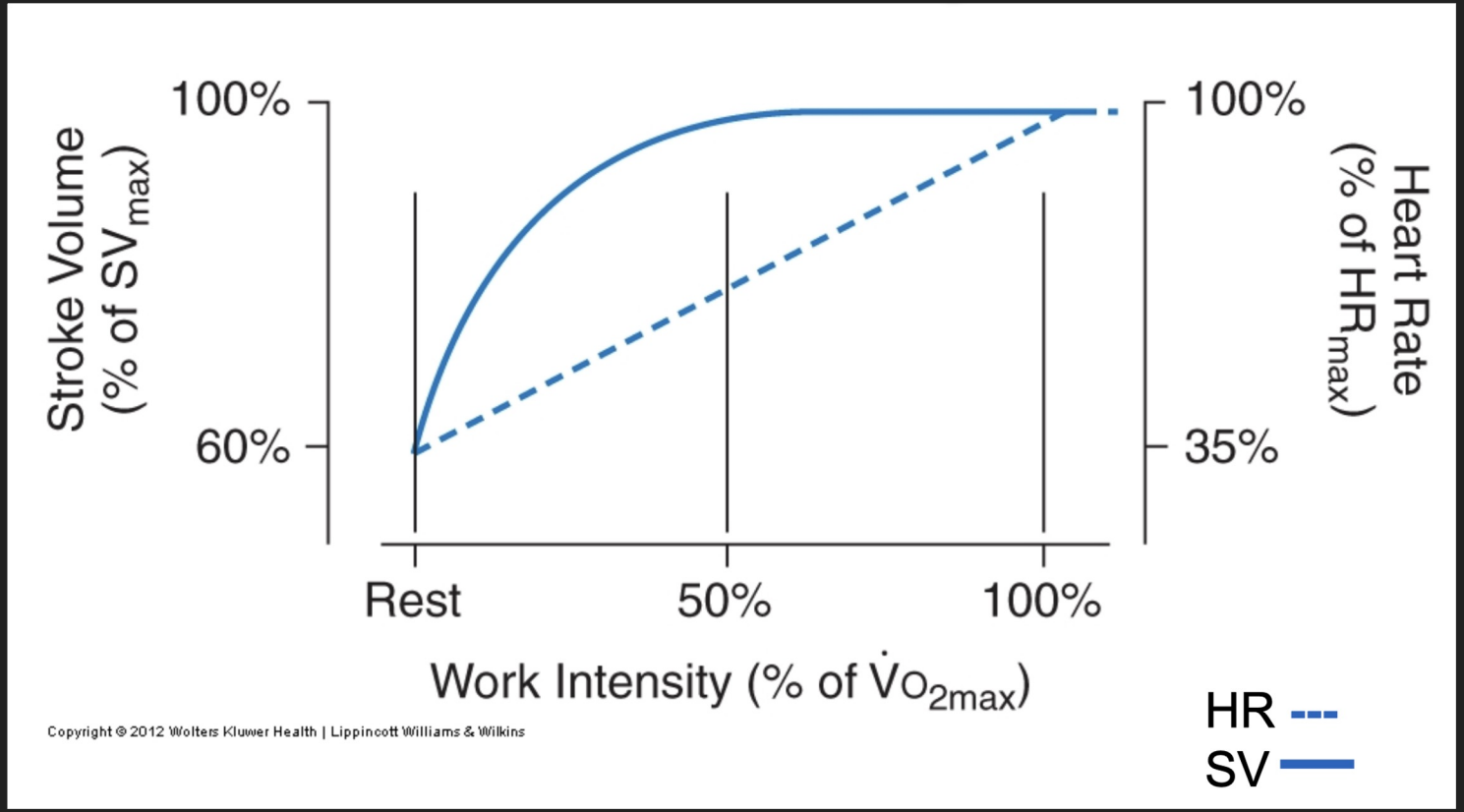
Therefore, VO_2 is increased by:

- Increased Q
- Increased peripheral a-vO_2 difference



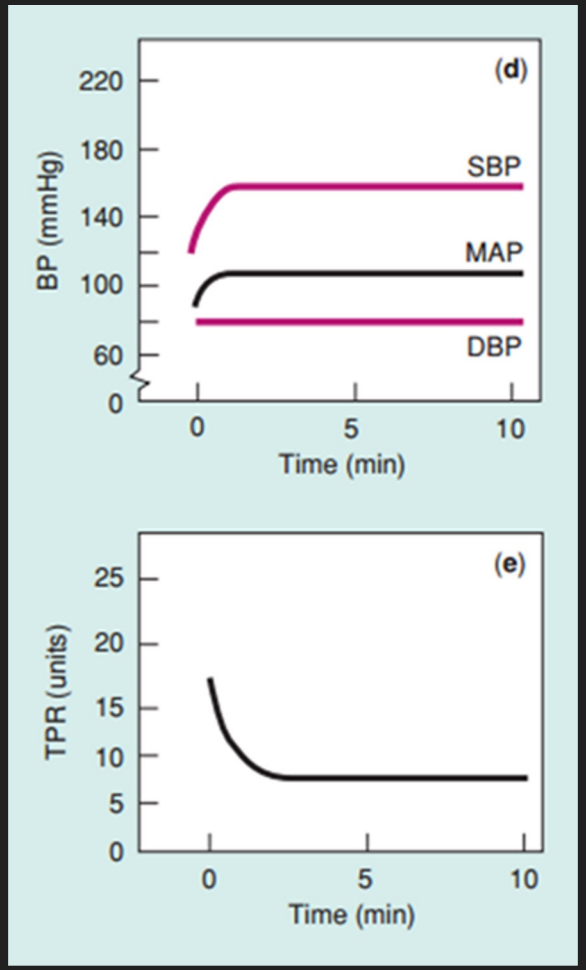


HR and SV increase with work intensity



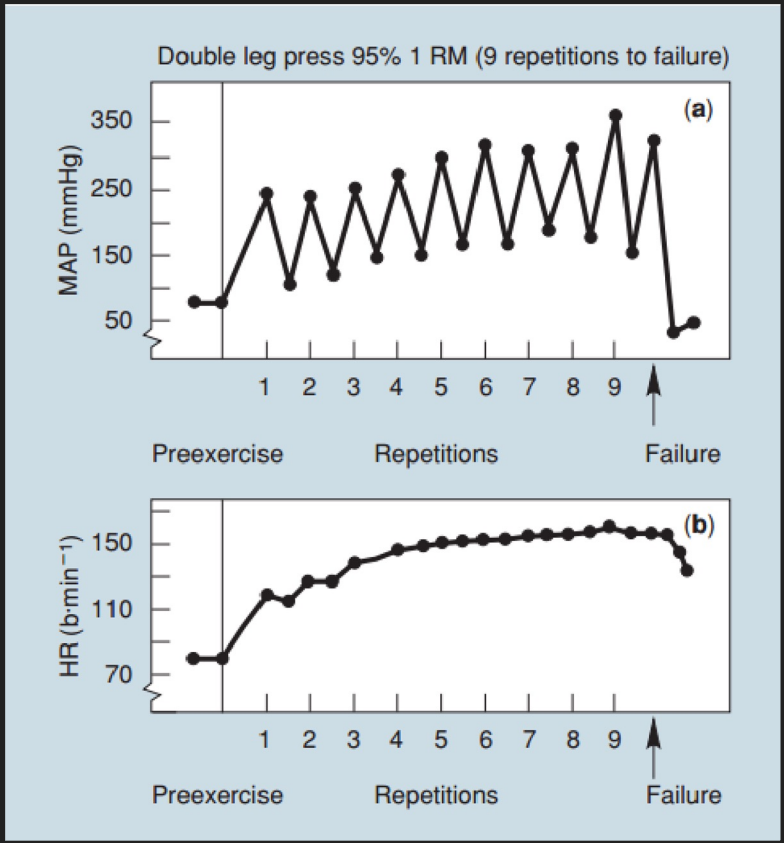
Blood Pressure Response

- BP = Q x TPR (total peripheral resistance)
- SBP rises as a result of increased Q
  - Response with exercise dependent on age (higher with age) and sex (higher in males)
- DBP remains same or moderately decreased
  - Vasodilation (facilitates blood flow to working muscles)
- TPR decreases due to vasodilation
  - Results in increasing blood flow to active muscles and keeps mean arterial pressure (MAP) from increasing dramatically
  - Functional Sympatholysis in a active skeletal muscle



Blood Pressure with Resistance Exercise

- When load is heavy, MAP and HR increase gradually with succeeding repetitions in a set to failure
- Dramatic BP increase due to mechanical compression of vessels and Valsalva
- TPR is higher during resistance than aerobic exercise because of vasoconstriction caused by pressor reflex



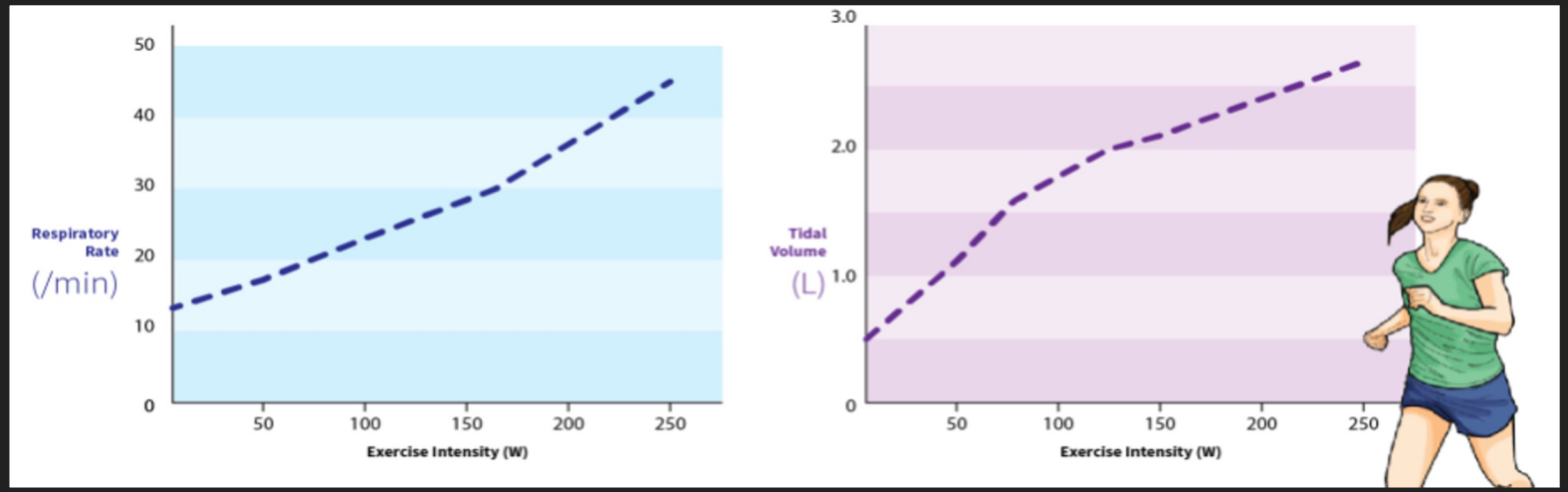
Responses to Physical Activity

Respiratory Physiology

Respiratory Response

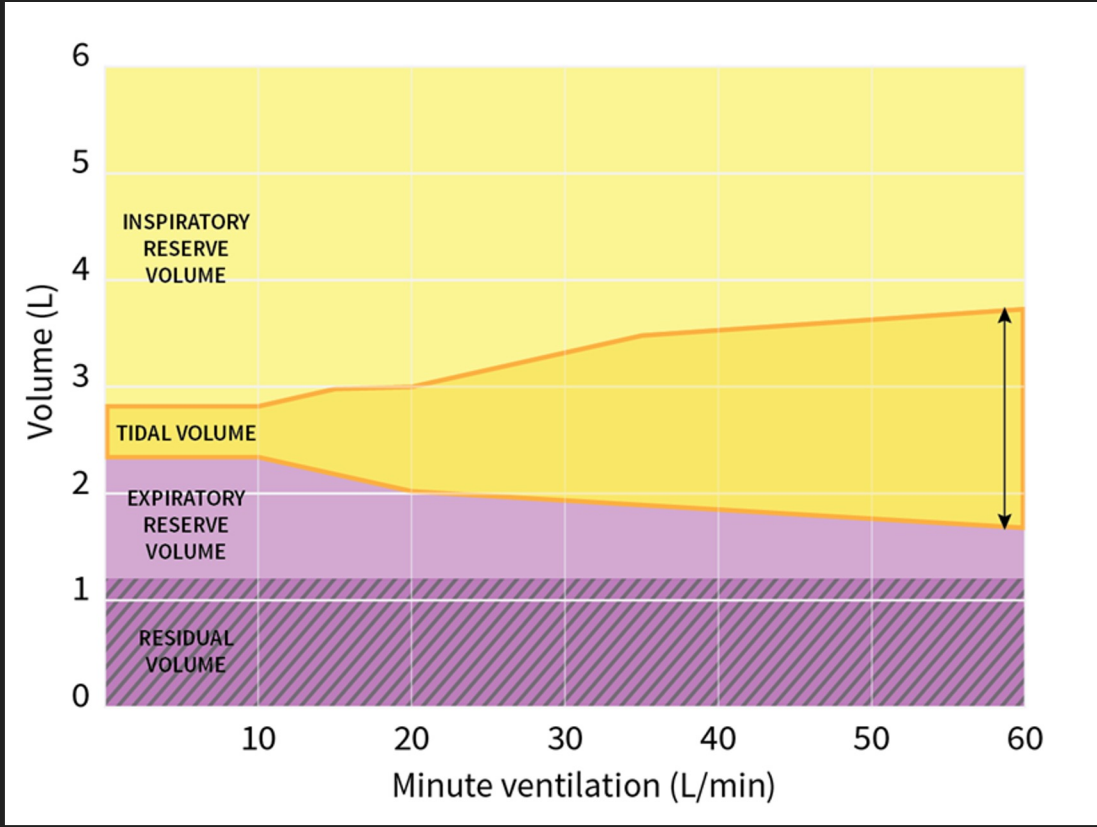
- Minute ventilation (V_E) increases with exercise
  - V_E = Tidal Volume (V_T) x respiratory rate (RR)
  - Both V_T and RR increase (depth and rate)

- Ventilatory demand is dependent on metabolic requirements, degree of lactic acidosis, dead space



Respiratory Response

- The increase in tidal volume comes at the expense of the expiratory and inspiratory reserve volumes.
- Need to get more air into alveolar ventilation to increase oxygenation of the blood

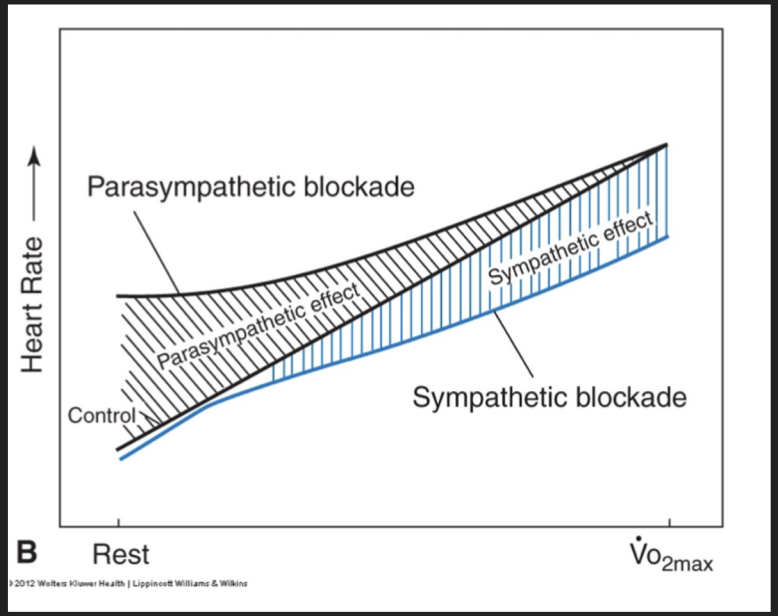


Recovery from Physical Activity

Cardiovascular + Respiratory

Heart Rate

- Heart Rate Recovery
  - Failure of HR to decrease by 12 bpm during first minute or by 22 bpm by end of second minute is strongly associated with an increased risk of mortality in patients with ischemic heart disease.
- Heart Rate Variability
  - Cardiac autonomic modulation post-exercise greatly depends on exercise duration and intensity
  - Not commonly measured post-exercise.
- Respiratory rate?



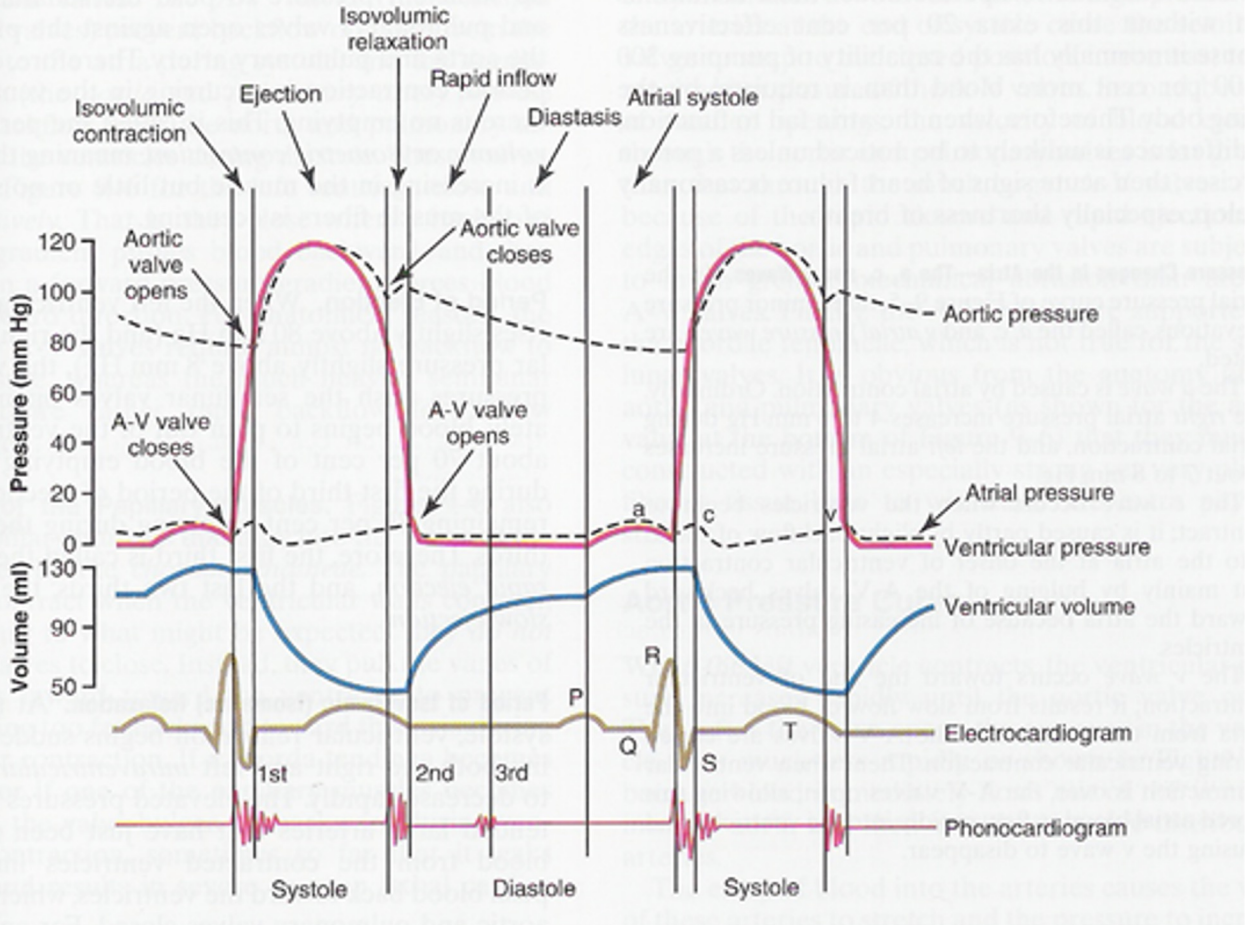
Type Property

heartRateRecoveryOneMinute Beta

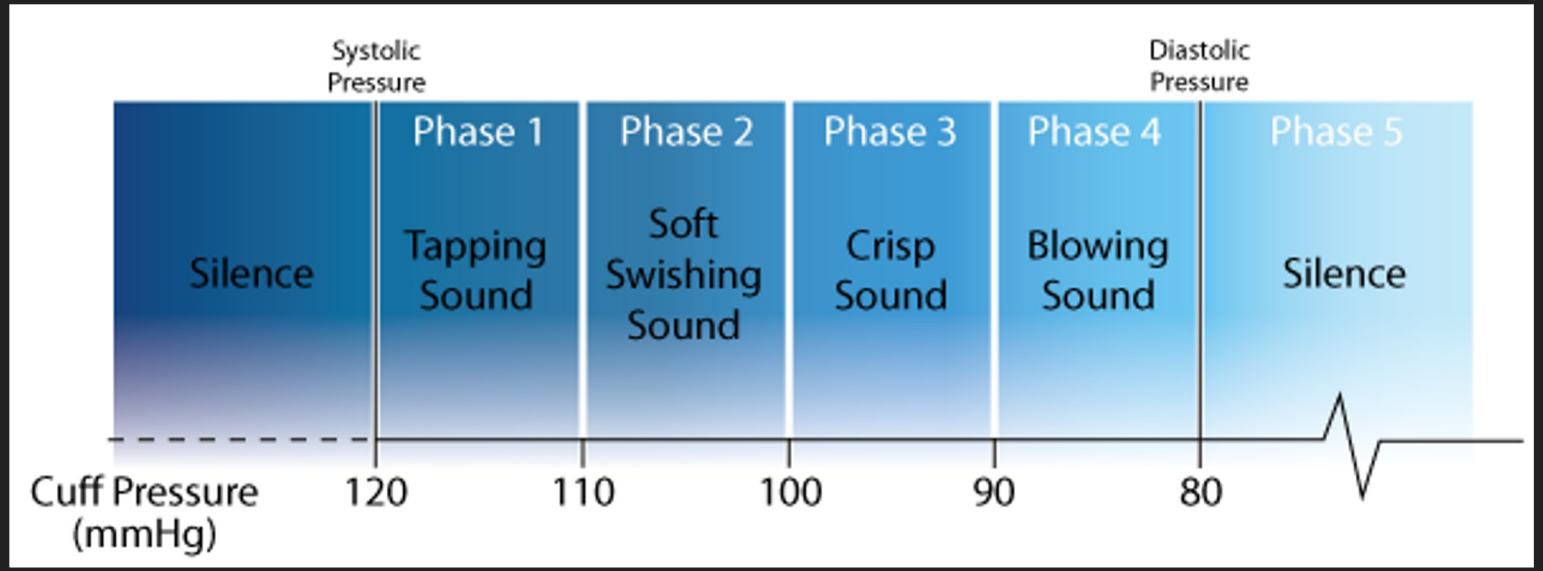
https://9to5mac.com/2022/04/05/apple-watch-heart-rate-recovery/

Other hemodynamics

- SBP declines due to rapid decrease in Q, reaching resting levels or lower within 6 minutes (in healthy adults).
  - Remains even lower than pre-exercise values for up to 12 hours.
  - “Post-exercise hypotension”
  - When exercise is terminated abruptly, there can be a drop in SBP because of venous pooling and delayed post-exercise increase in systemic vascular resistance to match the reduction in Q.
- Rate Pressure Product
  - Surrogate for myocardial oxygen uptake (HR * SBP)


Isovolumic relaxation
Ejection
Rapid inflow
Isovolumic contraction
Diastasis
Atrial systole
Aortic valve closes
Aortic valve opens
Aortic pressure
A-V valve closes
A-V valve opens
Atrial pressure
Ventricular pressure
Ventricular volume
Electrocardiogram
Phonocardiogram
Pressure (mm Hg)
Volume (ml)
120
100
80
60
40
20
0
130
90
50
a
c
v
R
P
Q
S
T
1st
2nd
3rd
Systole
Diastole
Systole

Korotkoff Sounds



Digital Stethoscope

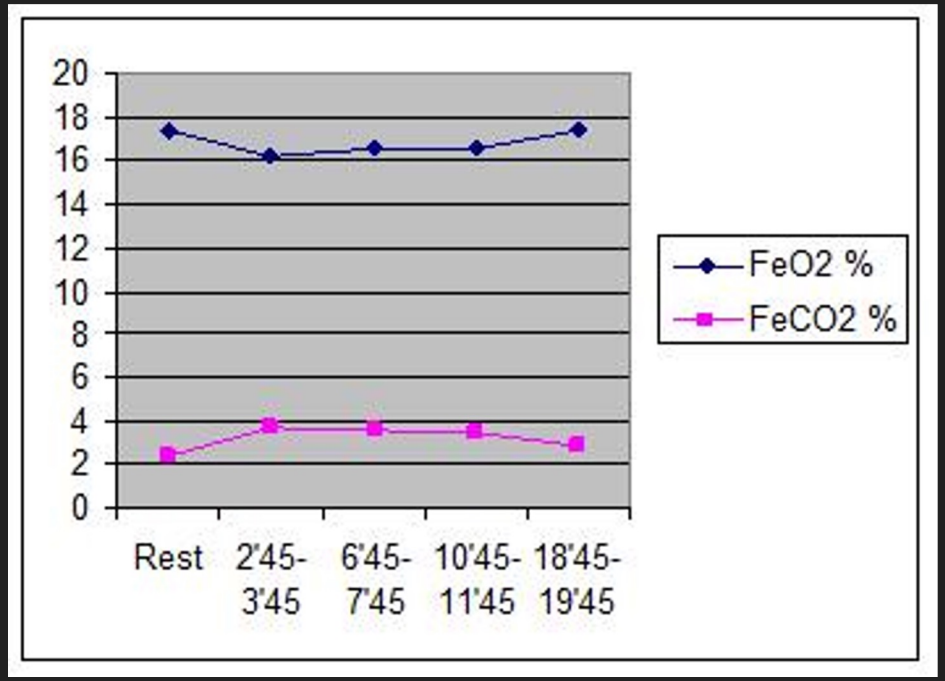
Electrocardiogram

Blood Pressure

Gas exchange

- FEO_2 (Fraction of expired air that is O_2)
  - Air we breathe in: 20.93%
  - We extract 3-6% (typically)
  - Therefore, air we exhale ~15-18%
  - Low values mean the subject is extracting O2 well and thus suggests that gas exchange in the alveoli is good.

- $FECO_2$
  - CO_2 in air: 0.03%
  - Most CO2 exhaled due to cellular metabolism
  - ~2.5-6% CO_2



To be continued…