Recovery from Physical Activity

The cardiorespiratory response and mobile health use cases

Conner McCraw, MS, RCEP
Clinical Exercise Physiologist
Software Engineer
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
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)

$VO_2 = \text{Cardiac Output (Q) x a-vO}_2$ difference

Therefore, $VO_2$ is increased by:

• Increased Q
• Increased peripheral a-vO$_2$ difference
HR and SV increase with work intensity

Graph showing the increase in Stroke Volume (% of SV$_{max}$) and Heart Rate (% of HR$_{max}$) with work intensity (% of VO$_{2max}$).
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?**
Building aerobic capacity. You spent 14 minutes at 80-90% of your max HR. This is 6 more minutes than you typically spend in this HR zone during Running.

Heart Rate
8:21 pm - 8:45 pm

Heart Rate
2:57
Indoor Cycle
143 BPM
12:54 PM - 1:16 PM

Recovery
151-109 BPM
1:16 PM - 1:19 PM

Recovery
-30 BPM after 1 min
-39 BPM after 2 min

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)
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 O$_2$ well and thus suggests that gas exchange in the alveoli is good.

- FECO$_2$
  - CO$_2$ in air: 0.03%
  - Most CO$_2$ exhaled due to cellular metabolism
  - ~2.5-6% CO$_2$
To be continued…