Chapter 11: Acid-Base Balance During Exercise
Objectives

• Define terms acid, base, and pH
• Discuss importance of acid-base regulation to exercise performance
• List principal intracellular and extracellular buffers
• Explain the role of respiration in the regulation of acid-base status during exercise
• Outline acid-base regulation during exercise
• Discuss principal ways that hydrogen ions are produced during exercise
Acids, Bases, and pH

• Acid
  – Molecule that can liberate H\(^+\) ions
• Base
  – Molecule that is capable of combining with H\(^+\) ions
• pH
  – Measure of H\(^+\) ion concentration

\[ \text{pH} = -\log_{10}[\text{H}^+] \]
pH of Blood

• Normal
  – pH = 7.4
• Acidosis
  – pH < 7.4
• Alkalosis
  – pH > 7.4
• Abnormal pH can disrupt normal body function and affect performance
Acidosis and Alkalosis

Accumulation of acids → Increase concentration of H^+ → Acidosis

Loss of bases → Increase concentration of H^+ → Alkalosis

pH scale: 7.4

Acidosis: pH drops
Alkalosis: pH rises

Loss of acids → Decrease concentration of H^+ → Alkalosis
Accumulation of bases → Decrease concentration of H^+ → Acidosis
Sources of Hydrogen Ions Due to Metabolic Processes

Fig 11.3
Importance of Acid-Base Regulation During Exercise

- Failure to maintain acid-base balance may impair performance
  - Inhibit ATP production
    - Stop glycolysis-inhibit PFK
  - Interfere with muscle contraction
    - Compete with calcium ions at binding sites on troponin
- Acid-base balance maintained by buffers
  - Release H\(^+\) ions when pH is high
  - Accept H\(^+\) ions when pH is low
Buffers

• Intracellular
  – Proteins
  – Phosphate groups
  – Bicarbonate

• Extracellular
  – Bicarbonate
  – Hemoglobin
  – Blood proteins

• Bicarbonate buffering system

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]
Regulation of Acid-Base Balance

• Lungs
  – Increased blood PCO$_2$
    • Results in low pH
    • Increases ventilation
    • CO$_2$ is “blown off”
    • pH increases

• Kidneys
  – Regulate blood bicarbonate concentration
  – Important in long-term acid-base balance
pH Changes During Exercise

• Blood pH
  – Declines with increasing intensity exercise
• Muscle pH
  – Declines more dramatically than blood pH
  – Muscle has lower buffering capacity
Changes in Arterial Blood and Muscle pH During Exercise

Fig 11.4
Buffering of Lactic Acid During Exercise

• Lactic acid is buffered by bicarbonate
  – Increases in lactic acid accompanied by decreases in bicarbonate and blood pH

• Respiratory compensation
  – “Blows off” excess CO$_2$

• CO$_2$ + H$_2$O $\leftrightarrow$ H$_2$CO$_3$ $\leftrightarrow$ H$^+$ + HCO$_3^-$
Changes in Blood Lactic Acid, $\text{HCO}_3^-$, and pH During Exercise

Fig 11.2
Regulation of Acid-Base Balance During Exercise

• First line
  – Cellular buffers
    • Proteins, bicarbonate, and phosphate groups
      – Weak acids that can combine with $\text{H}^+$
    – Blood buffers
      • Bicarbonate, hemoglobin, and proteins
Regulation of Acid-Base Balance During Exercise

- Second line
  - Respiratory compensation

- \( \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \)