Adaptations to the Endocrine System

Lecture Overview
- Blood hormone concentration
- Hormone-receptor interaction
- Regulation and action
- Hormonal control of substrate mobilization during exercise

Neuroendocrinology
- Two major homeostatic systems involved in the control & regulation of various functions (cardiovascular, renal, metabolic, etc.)
  - Nervous system
  - Endocrine system
    - Releases hormones into the blood to circulate to tissues
- Endocrine glands release hormones (chemical messengers) directly into blood
  - The blood carries the hormone to a tissue to exert an effect
  - The binding of a hormone to a specific protein receptor allows the hormone to exert its effect
Hormones

• Hormones can be divided into several classes based on chemical makeup:
  – Amino acid derivatives
  – Peptides/protein
  – Steroids
• The chemical structure influences the way in which the hormone is transported in the blood & the manner in which it exerts its effect on the tissue
• Hormones exist in very small quantities in the blood (microgram, nanogram, picogram)

Blood Hormone Concentration

• The hormone concentration in the plasma is dependent upon:
  – The rate of secretion of the hormone from the endocrine gland
  – The rate of metabolism or excretion of the hormone
  – The quantity of transport protein (for some hormones)
  – Changes in plasma volume

Hormone-Receptor Interaction

• Mechanism by which hormones modify cellular activity include:
  – Membrane transport
    • After hormone binds to receptor on a membrane, carrier molecules activated in or near membrane to increase the movement of substrates or ions from outside the cell to inside the cell
  – Stimulation of DNA in the nucleus
    • Lipid-like structure allows steroids to diffuse through cell membranes & bind to receptors in the cytoplasm. This complex enters nucleus & binds to a specific protein linked to DNA and DNA synthesis
  – Second messengers
    • Some hormones cannot easily cross membrane. They bind to a receptor on the membrane which activates a G protein. This interaction may open an ion channel or activate an enzyme
### Major Endocrine Glands

- Hypothalamus & pituitary gland
- Thyroid gland
- Parathyroid gland
- Adrenal gland
- Pancreas
- Testes & ovaries

### Hypothalamus & Pituitary Gland

- The hypothalamus controls the activity of both the anterior pituitary & posterior pituitary glands
- Growth hormone (GH) is released from the anterior pituitary gland & is essential for normal growth
- GH increases during exercise to mobilize fatty acids from adipose tissue & to aid in the maintenance of blood glucose
- Antidiuretic hormone (ADH) is released from the posterior pituitary gland & reduces water loss from the body

### Thyroid Gland

- Thyroid hormones $T_3$ (triiodothyroine) & $T_4$ (thyroxine) are important for maintaining the metabolic rate and allowing other hormones to bring about their full effect
- Calcitonin is involved in a minor way in the regulation of plasma calcium
Parathyroid Gland

- Parathyroid hormone is the primary hormone involved in plasma calcium regulation
- Exercise increases the concentration of parathyroid hormone in the plasma

Adrenal Gland

- Adrenal Medulla
  - The adrenal medulla secretes the catecholamines epinephrine (E) and norepinephrine (NE). E is the adrenal medulla’s primary secretion (80%), while NE is primarily secreted from the adrenergic neurons of the sympathetic nervous system.
  - E & NE bind to α and β adrenergic receptors and bring about changes in cellular activity (e.g. increased heart rate, mobilization of fatty acids from adipose tissue) via second messengers

Adrenal Gland

- Adrenal Cortex
  - The adrenal cortex secretes aldosterone, cortisol, and estrogens and androgens (sex steroids)
  - Aldosterone regulates sodium & potassium balance. Aldosterone secretion increases with strenuous exercise
  - Cortisol responds to a variety of stressors, including exercise, to ensure that fuel (glucose & free fatty acids) is available, and to make amino acids available for tissue repair
Pancreas

- Insulin is secreted by the β cells of the islets of Langerhans in the pancreas and promotes the storage of glucose, amino acids, and fats
- Glucagon is secreted by the α cells of the islets of Langerhans in the pancreas and promotes the mobilization of glucose and fatty acids

Testes & Ovaries

- Testosterone & estrogen establish and maintain reproductive function and determine secondary sex characteristics
- Chronic exercise (training) can decrease testosterone levels in males and estrogen levels in females

Hormones & Exercise

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth Hormone</td>
<td>Increase</td>
</tr>
<tr>
<td>ADH</td>
<td>Increase</td>
</tr>
<tr>
<td>T3 &amp; T4</td>
<td>Increase</td>
</tr>
<tr>
<td>Calcitonins</td>
<td>Unknown</td>
</tr>
<tr>
<td>Parathyroid hormone</td>
<td>Increase</td>
</tr>
<tr>
<td>Cortisol</td>
<td>Increase (heavy)</td>
</tr>
<tr>
<td></td>
<td>Decrease (light)</td>
</tr>
<tr>
<td>Aldosterone</td>
<td>Increase</td>
</tr>
<tr>
<td>E &amp; NE</td>
<td>Increase</td>
</tr>
<tr>
<td>Insulin</td>
<td>Decrease</td>
</tr>
<tr>
<td>Glucagon</td>
<td>Increase</td>
</tr>
<tr>
<td>Testosterone</td>
<td>Small increase</td>
</tr>
<tr>
<td>Estrogen</td>
<td>Small increase</td>
</tr>
</tbody>
</table>
Hormonal Control of Substrate Utilization During Exercise

- Type of substrate and rate at which it is utilized during exercise depend strongly on the intensity & duration
  - Strenuous - mostly CHO oxidation
  - Prolonged, moderate intensity - increase in fat oxidation as CHO stores are depleted

Muscle-Glycogen Utilization

- At the onset of most types of exercise & for very strenuous exercise, muscle glycogen is the primary CHO fuel for muscular work
  - Intensity is inversely related to duration
  - Intensity determines rate at which muscle glycogen is used as fuel
- The heavier the exercise, the faster glycogen is broken down (glycogenolysis)
  - Glycogenolysis is initiated by second messengers, which activate protein kinases in the cell

Blood Glucose Homeostasis During Exercise

- A focal point of hormonal control systems is the maintenance of the plasma glucose concentrations
- Plasma glucose concentration is maintained through 4 different processes:
  1. Mobilization of glucose from liver glycogen stores
  2. Mobilization of plasma FFA from adipose tissue to spare plasma glucose
  3. Synthesis of new glucose in the liver from amino acids, lactic acid, and glycerol
  4. Blocking of glucose entry into cells to force the substitution of FFA as a fuel
Blood Glucose Homeostasis During Exercise

- The hormones thyroxine, cortisol, and growth hormone act in a permissive manner to support the actions of other hormones during exercise.
- Growth hormone and cortisol also provide a "slow-acting" effect on CHO and fat metabolism during exercise.

Blood Glucose Homeostasis During Exercise

- The decrease in plasma insulin and the increase in plasma E, NE, GH, glucagon, and cortisol during exercise control the mechanisms to maintain glucose concentration.
- Glucose is taken up 7 to 20 times faster during exercise than at rest - even with the decrease in plasma insulin.
- Training causes a reduction in E, NE, glucagon and insulin responses to exercise.