chapter 4

Endocrine Responses to Resistance Exercise
Chapter Objectives

• Understand basic concepts of endocrinology.
• Explain the physiological roles of anabolic hormones.
• Describe hormonal responses to resistance exercise.
• Develop training programs that demonstrate an understanding of human endocrine responses.
It has been theorized that the endocrine system can be manipulated naturally with resistance training to enhance the development of various target tissues, thereby improving performance.
Key Term

• **Endocrine glands**: Body structures specialized for releasing hormones into the blood.

• **Hormones**: Chemical messengers that are synthesized, stored, and released into the blood by endocrine glands and certain other cells.

• **Anabolic hormones**, such as insulin, insulin-like growth factors, testosterone, and growth hormone, promote protein synthesis and tissue building.
Principal Endocrine Glands of the Body

- Insulin
- Insulin-like Growth Factor
- Testosterone
- Growth Hormone
- Cortisol
- Catecholamines
- Insulin
- Parathyroid glands
- Thyroid gland
- Pituitary gland (anterior and posterior)
- Hypothalamus
- Heart
- Liver
- Adrenal glands (medulla and cortex)
- Pancreas
- Kidneys
- Ovaries (in female)
- Testes (in male)
Muscle as the Target for Hormone Interactions

• Hormones are intimately involved with protein synthesis and degradation mechanisms that are part of muscle adaptations to resistance exercise.

• This includes both anabolic (promote tissue building) and catabolic (degrade cell proteins) hormones.
Heavy Resistance Exercise and Hormonal Increases

• Hormones are secreted before, during, and after the resistance exercise bout due to the physiological stress of resistance exercise.

• As few as one or two heavy resistance exercise sessions can increase the number of androgen receptors in the muscle.
Lock-and-Key Theory for Hormonal Action

- Muscle is a Target for Hormone Interactions
Action of Steroid Hormones (eg, testosterone)

1. The steroid hormone enters a cell.
2. The hormone binds to a specific receptor in the cytoplasm or in the nucleus.
3. The hormone-receptor complex enters the nucleus and activates the cell's DNA, which forms RNA.
4. The mRNA leaves the nucleus and enters the cytoplasm.
5. The mRNA directs protein synthesis in the cytoplasm.
Roles of Receptors in Mediating Hormonal Changes

• The inability of a hormone to interact with a receptor is called *downregulation*.

• Alterations to a receptor’s binding characteristics or the number of receptors can be as dramatic in adaptation as the release of increased amounts of hormone from an endocrine gland.
Key Points

• Heavy resistance exercise results in an increase in the blood concentrations of anabolic hormones.

• The specific force produced in activated fibers from resistance training stimulates receptor and membrane sensitivities to anabolic factors, including hormones, which lead to muscle growth and strength changes.

• Receptors are less sensitive when muscle fibers are close to their genetic ceiling for cell size, or when stress is excessive (e.g., overtraining), and catabolic actions in muscle may occur in part due to the inability of anabolic hormones to bind to muscle receptors.
Adaptations in the Endocrine System

- Examples of the potential types of adaptation with resistance exercise:
  - Amount of synthesis and storage of hormones
  - Transport of hormones via binding proteins
  - Increases in hormone concentration in blood
  - Time needed for the clearance of hormones through liver and other tissues
  - Amount of hormonal degradation that takes place over a given period of time
  - How much blood-to-tissue fluid shift occurs with exercise stress (can affect blood hormone concentration levels)
  - Number of receptors in muscle tissue (increases as a result of training)
Primary Anabolic Hormones

• There are three primary anabolic hormones involved in muscle tissue growth and remodeling:
  – Testosterone
  – Growth hormone (GH)
  – Insulin-like growth factors (IGFs)
Primary Anabolic Hormones

• Testosterone
  – The primary androgen hormone that interacts with skeletal muscle tissue
  – Effects on muscle tissue: protein synthesis, increased strength and size of skeletal muscle, increased force production potential and muscle mass
    • may enhance nervous system development in long-term training, such as neural adaptations that occur for strength gain in highly trained strength/power athletes.
  – Women have 15- to 20-fold lower concentrations of testosterone than men, and if acute increases occur after a resistance training workout, they are small.
    • testosterone concentration can vary substantially between individual women
Primary Anabolic Hormones

• Testosterone
  – Heavy resistance training using one or two repetitions in low volume, which may not cause any changes in testosterone concentrations after a workout, could potentially still increase the absolute number of receptors and thus binding sites available to testosterone.
  – This effect on receptors has yet to be fully elucidated.
Serum Testosterone Responses to Exercise

- Male (green bars) & female (gold bars) serum testosterone responses to two exercise programs:
  - **Strength** protocol (a): 8 exercises using 5RM & 3 min rest between sets & exercises (↓response compared to protocol b)
  - **Hypertrophy** protocol (b): 8 exercises using 10RM & 1 min rest between sets & exercises (total work for 2nd protocol was higher)
  - * = significantly above preexercise levels
  - + = significantly above the female group

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Key Point

• To maximize Increases in Serum Testosterone Concentration:
  – Use large muscle group exercises (e.g., squats, bench press, deadlifts, power clean)
  – Use heavy resistance (75-95% of 1 RM; 2-10 RM)
  – Use moderate to high volume of exercise, with multiple sets (3 or greater) and exercises
  – Use short rest intervals (1 min more effective than 3 min)
  – Long term training (> 2 years)
• **Growth Hormone**
  - Interacts directly with target tissues, which include bone, immune cells, skeletal muscle, fat cells, and liver tissue
  - Regulated by neuroendocrine feedback mechanisms and mediated by secondary hormones
Primary Anabolic Hormones

- Physiological functions of Growth Hormone
  - Decreases glucose utilization
  - Decreases glycogen synthesis
  - Increases amino acid transport across cell membranes
  - Increase protein synthesis
  - Increases lipolysis (fat breakdown) and utilization of free fatty acids
  - Stimulates cartilage growth
Primary Anabolic Hormones

• Growth Hormone
  – Efficacy of Pharmacological Growth Hormone
    • Pharmacological use of GH has unknown and unpredictable results.
  – Growth Hormone Responses to Stress
    • GH responds to exercise stressors, including resistance exercise.
    • Like testosterone, GH increases in response to higher volume and intensity training and lower rest periods
Key Point

- Growth hormone is important for the normal development of a child and appears to play a vital role in adapting to the stress of resistance training. Short rest period types of workouts result in greater serum concentrations compared to long rest protocols of similar total work.
Primary Anabolic Hormones

• Insulin-Like Growth Factors
  – Exercise Responses of Insulin-Like Growth Factors
    • GH stimulates the liver to synthesize and secrete Insulin-like growth factor I (IGF-I)
    • IGF-I is most studied because of its role in protein synthesis (anabolism).
    • Exercise results in acute increases in blood levels of IGF-I.
    • Adaptations to heavy resistance training of IGF-I in the various tissues still require further investigation.
Changes in IGF-I appear to be based on the starting concentrations before training.

- If basal concentrations are low, IGF-I increases, if high concentrations, there is no change or IGF-I decreases.
The Adrenal Hormones

• Cortisol
  – Role of Cortisol
  • Catabolic effects
    – Converts amino acids to carbohydrates, increases the level of enzymes that break down proteins, and inhibits protein synthesis
    – Has greater effect on Type II fibers than Type I fibers.
  – Resistance Exercise Responses of Cortisol
    • Although catabolic effects of cortisol increases with resistance training, anabolic effects of GH and testosterone normally increases to a greater extent.
    • Prolonged training may reduce the negative effects cortisol due to adaptation processes.
Key Points

• Resistance exercise protocols that use high volume, large muscle groups, and short rest periods result in increased serum cortisol values (catabolic), but results in an even greater increase in testosterone and GH values (anabolic).

• Though chronic high levels of cortisol may have adverse catabolic effects, such as what results with overtraining, acute increases may contribute to the remodeling of muscle tissue and maintenance of blood glucose.
The Adrenal Hormones

• **Catecholamines**
  – Role of Catecholamines (primarily epinephrine, which is released upon neural stimulation from the brain)
    • Increase force production via central mechanisms and increased metabolic enzyme activity
    • Increase muscle contraction rate
    • Increase blood flow and blood pressure
    • Increase energy availability
    • Augment secretion rates of other hormones, such as testosterone
  – Training Adaptations of Catecholamines
    • Prolonged heavy resistance training results in increased secretion of epinephrine during maximal exercise
Key Point

• Training protocols must be varied (periodization to prevent overtraining and chronic fatigue) to allow the adrenal gland to engage in recovery processes (secrating less cortisol) and prevent the chronic catabolic effects of cortisol, which can have negative effects on the immune system and protein synthesis.