Endocrine System

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The Endocrine System

The endocrine system is a complex network of integrated organs that communicates and helps regulate all other bodily systems to manage the internal activities and maintain homeostasis. Within the body, fine balances exist, with seemingly unlimited cause and effect patterns which occur in response to internal and external variations of environment. Although the systems of the body are often viewed independently, they are actually intimately integrated and cannot function autonomously. The relationship between the muscular system and the nervous system would seem to be a logical example of the interaction of networked systems because, in essence, nerves are the brains behind the machine. A muscle cannot function without neural communication. Additionally, for the musculoskeletal system to function, the gastrointestinal system must supply it with nutrients for energy and building blocks, and the pulmonary system must work cooperatively with the cardiovascular system to deliver nutrients and oxygen, while simultaneously eliminating waste products of cellular metabolism, including CO₂. A not so obvious relationship also exists between the muscular and endocrine systems. Most fitness professionals maintain a very limited knowledge of this relationship beyond that it actually exists. Due to the fact that adaptations to exercise depend upon this relationship, trainers must understand how to manipulate the systems to optimize health improvements and maximize performance.

Hormones

A gland is an organ that produces a secretion for use elsewhere in the body or in a body cavity. When endocrine glands produce and release hormones, they do so for communication purposes. Hormones essentially direct actions of other tissues via chemical messaging. During and following physical activity, these endocrine glands must regulate electrolyte activity, acid/base balance, and manage energy for biological work and recovery. They do so by producing hormones, which enter circulation and are picked up by the appropriate receptor on target cells.

Cellular receptors are small proteins on the outside of cells that bind to hormones and transmit the information into those cells to regulate the cells’ behaviors. These receptors are generally specific to a single hormone and not all cell types have every type of receptor. The concentration and location of hormone receptors depend upon the specific responsibility of the hormone. Thus only the tissue that is supposed to receive the information gets the information, alleviating confusion within the body. This internal policy of communication is called target cell specificity. An easy analogy to make is when you send e-mail. Think of yourself as a gland and the e-mail as the hormone. When you send that e-mail, it travels across the internet which is accessed by millions of people; however, the information on that e-mail is only received by the one or more persons you designate as recipients.

~Key Terms~

Endocrine system- Body control system composed of a group of glands that maintain a stable internal environment by producing chemical regulatory substances called hormones.

Homeostasis- The tendency of the body to seek and maintain a condition of balance or equilibrium within its internal environment, even when faced with external changes.

Eustress- A positive, desirable form of stress that influences physical or physiological health.

Distress- A negative form of stress that influences physical or physiological health.
Hormones are categorized into two classes: **steroids** (lipid based) and **polypeptides** (protein based). The type and structural foundation of the hormone is most often related to its message and the tissue that is supposed to receive it.

The intricacy of the specific activity each hormone regulates is often rather sophisticated. The information that a hormone relays to a target tissue depends on the type of tissue it binds to, what other hormones are binding to that tissue at that time, and the cellular environment of the tissue. The endocrine system is further complicated by the fact that certain organs that are not endocrine glands can release hormones. In addition to the hormones of the endocrine glands, at least eight other hormones come from alternate sources, including the stomach, duodenum, kidneys, heart, and plasma membranes of different bodily cells. However, for the purposes of this text, the focus will be specific to hormones and tissues most relevant to physical activity and the consequential adaptations that come from participation in varying types of exercise.

Due to the fact that hormones are not produced at a constant rate, but rather act in a more surge-like manner (in response to variations in physiological and psychological demand), exercise and related stress have a notable effect on hormone activity (9; 28; 45). Most of the endocrine glands do not store a large reserve of hormone, and the amount of hormones synthesized by the respective gland tends to equal the hormone release. Therefore, rapid adjustments in production and excretion must be made to regulate the body’s internal conditions when the environment changes.

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**Key Terms**

**Hormone receptors** - A receptor protein on the surface of a cell or in its interior that binds to a specific hormone.

**Target cell specificity** - Hormones circulate to all tissues but influence only certain cells due to the presence of receptors on or in the cells.

**Steroid** - Any of a group of organic compounds belonging to the general class of biochemicals called lipids, which are easily soluble in organic solvents and slightly soluble in water.

**Polypeptides** - A small protein typically between 10 and 100 amino acids in length.
changes from rest to activity. Generally, hormonal balance is consistent with chemical uptake of hormone receptors and rate of removal by the liver and kidneys. It would seem that the body constantly attempts to control concentration levels to maintain equilibrium so that hormones are only available to target tissues when needed.

~Quick Insight~

Exercise, psychological stress, physiological stress, and immune function all intertwine. The immune system is closely tied to the adaptation response to physical training. Likewise, psychological stress negatively affects recovery response and immune function. The body can only handle so many demands at one time, so when it is laboring in response to exercise and stress, it suppresses immune function. Likewise, when the body is fighting an illness, exercise response is negatively impacted. Other stressors, such as lack of sleep, poor nutrition, alcohol consumption, and mental stress can magnify this impact. Each factor independently affects immune function and status; therefore a long-term exposure to compound stressors can increase susceptibility to illness and disease. One of the more common illnesses contracted during periods of imbalanced stress and recovery is an upper respiratory tract infection. Often times, exercisers question whether it is beneficial to exercise when affected by an illness. Since exercise suppresses immune function, and post-exercise immune status increases susceptibility to microbe invaders, it would be prudent not to exercise when fighting an illness.

Pituitary Hormones

Probably the most notable and easily recognized hormones to those familiar with exercise are the anabolic hormones. These include growth hormone, testosterone and the insulin-like growth factors, as well as insulin and thyroid hormones. Each plays a role in muscle remodeling and the adaptation effects produced from exercise (14; 35; 65). Growth hormone (GH), also called somatotropin, is excreted by the anterior pituitary gland and is one of the most relevant hormones in the body, as it has extensive responsibilities related to physiological activity (4; 65). It promotes cell division and proliferation throughout the body by facilitating protein synthesis (3). It does this by increasing amino acid (the building blocks of proteins) transport through plasma membranes, stimulating RNA formation, and activating cellular ribosomes (2). GH also protects glycogen reserves and carbohydrate breakdown by encouraging the mobilization and utilization of lipids for fuel during exercise.

The secretion of GH is regulated by the hypothalamus in the brain. The hypothalamus, which measures bodily stress, sends GH releasing-factor (GH-RF) hormones to the pituitary, which stimulates pituitary secretion of GH. During physical activity, GH is released based on the level of intensity. The more intense the exercise or demand, the greater the secretion and subsequent blood concentration level of GH. The hypothalamus releases GH-RF in response to low blood glucose, increased levels of certain amino acids, and stress, all of which occur during intense exercise. The hypothalamus also releases somatostatin, which inhibits GH secretion in response to high blood glucose common during inactivity. The elevation in GH during acute exercise benefits the active tissue and positively mediates energy metabolism (30). This action allows for prolonged work as the body relies on lipids for fuel, while sparing carbohydrates (29). The quantity of GH released seems to be dependent upon the relative intensity (39). When untrained and trained individuals exercise to exhaustion, similar levels of GH are released. However, untrained individuals show greater concentrations post exercise (50). Likewise, during acute submaximal bouts, untrained individuals, when compared to conditioned individuals, show higher levels of GH (49). These findings suggest that the perceived demand on the body determines the quantity of the GH production in response to exercise intensity (39). The presumed mechanism for increases in GH production and secretion is through stimulation of the hypothalamus, originating from the active tissues. In a practical sense, notable improvements in strength, power, and muscle size require higher intensity training (17). This may sound obvious, but the mechanism is still somewhat unclear to researchers.

The anabolic effect GH has on muscle mass, cartilage formation, and bone through the augmentation of protein synthesis often occurs in conjunction with another hormone, insulin-like growth factor (IGF) (34). The interaction of IGF polypeptides and GH seems to be the main reason muscle fibers adapt, by increasing the magnitude of their protein structures (20). The liver is the organ responsible for IGF secretion, as dictated by the GH stimulation of liver cell DNA (34). The IGF binds to proteins, which transport and supervise the physiological mechanisms of the hormones (19).

Testosterone has often been implicated as the premier anabolic hormone (probably due to the notable effect of steroids), but it seems that the direct effect testosterone has on fiber hypertrophy is not as significant as that of IGF (37). IGF directly increases protein synthesis activity. Testosterone’s main contribution to muscle hypertrophy is more likely from the effect it has on increasing the quantity of GH released from the
pituitary gland and the synergistic augmentation of GH response on target tissues, rather than through its direct effect on muscle cell DNA activity (37).

**Gonadal Hormones - Testosterone**

Testosterone is produced in the gonadal glands of men and women. It is the primary androgenic hormone (dihydrotestosterone) for secondary male characteristics. It is also the primary hormone responsible for muscle tissue interaction, which explains the visual and measurable differences between men and women. Testosterone, though, is not a male or female hormone, as it exists in both men and women alike. There are, though, distinct differences in the concentration of the hormone within the respective genders, as males demonstrate much higher levels of circulating testosterone than women.

Testosterone’s contribution to anabolic activity helps characterize the differences in lean mass and strength found between men and women (56). Although the concentration of testosterone in women is ten times less than that in men, concentrations will increase in response to exercise in both genders (40). Similar to testosterone, estrogen is not a gender-specific hormone. Testosterone is converted into estrogen (estradiol) in men and aids in the maintenance of bone throughout a male’s lifespan. Estrogen is a key hormone in bone maintenance in both men and women. When men inject testosterone or take testosterone precursors such as Dehydroepiandrosterone (DHEA), Androstenediol, or Androstenedione, the body perceives excessively high concentrations and thus attempts to re-establish hormonal balance by converting the excess testosterone to estradiol (6; 7). This explains why male steroid users may develop breast tissue called gynecomastia.

When testosterone interacts with muscle tissue, it does so through direct and indirect mechanisms. As previously mentioned, testosterone increases pituitary activity, causing the release of GH, which in this case, would be an indirect influence on protein synthesis in the tissue (38). Testosterone does have direct communication with DNA. This relationship identifies the direct path testosterone takes to encourage increased protein synthesis. Testosterone also interacts with the nervous system to enhance strength and size via direct influence on neurons and structural protein changes. Increases in testosterone concentrations are attributed to high intensity exercise.

**Pancreatic Hormones**

The pancreas has two main functions. The first is the production of digestive enzymes that are released into the small intestines to break down fat, carbohydrates, and protein so that they can be absorbed into the blood stream. The second function, which is more important to this discussion, is the regulation of blood sugar levels by the release of two endocrine hormones known as insulin and glucagon.

When you eat a meal, carbohydrates are broken down primarily into simple sugars so that they can be absorbed by the blood stream. The most common sugar they are broken down to is glucose. When glucose is absorbed into the blood stream, the concentration level is measured by pancreatic receptors as the blood flows through the pancreatic tissue. The total quantity of the glucose is referred to as the glycemic load. This causes insulin to be released into the blood stream from the beta cells in the islet of Langerhans, located in the pancreas. The pancreas attempts to maintain a steady-state level of blood glucose. After a meal, when the blood sugar rises, this release of insulin drives glucose into the muscle and liver cells to be stored as glycogen (8). Insulin also pushes some of the excess sugar into the fat cells where the imported glucose is converted into triglycerides to reduce the blood glucose to normal steady-state levels. When insulin is appropriately regulated, carbohydrate levels in the blood do not surpass the apparent glucose concentration threshold, thereby reducing the propensity of insulin to facilitate fat cell uptake of sugar (8). In the absence of insulin, fat cells mobilize fatty acids to fuel energy demands. This identifies the relevance of lower glycemic loads upon the metabolic system to control insulin release. For optimal fat utilization and a reduced risk of fat storage caused by high blood glucose concentrations, dietary intake of excess calories, simple sugars, and processed carbohydrates should be controlled.

If the body experiences low blood glucose levels, a condition known as hypoglycemia, the alpha cells in the pancreas are stimulated to release glucagon. Glucagon quickly travels to the liver to stimulate the release of stored glucose in the form of glycogen into circulation to raise and stabilize blood glucose levels back to a steady-state level. Blood insulin and blood glucose will decrease as a function of prolonged exercise duration (23). The presence of catecholamines cause an

~Key Terms~

**Lipids**- A group of organic molecules that includes fats, oils, and waxes.; lipids store energy and form parts of cell structures, such as cell membranes.

**Ribosomes**- Small particles, present in large numbers in every living cell, whose function is to convert stored genetic information into protein molecules.
inhibitory effect on beta cells in the pancreas, leading to a reduction in circulating insulin levels (24). This drop in insulin levels is matched by an enhancement of muscle cellular permeability to energy substrates such as glucose and fats. Concurrently, liver cells become more sensitive to glucagon and epinephrine to raise and sustain glucose levels during exercise (41). As the exercise duration increases, so too does the contribution of fatty acids due to a reduced insulin secretion and the progressive decrease in glycogen reserves.

It is important to understand that insulin is anabolic in nature. It is true that the major function of insulin is to regulate glucose metabolism in the tissues through facilitated diffusion, but insulin is more anabolically dynamic than many people realize (5). Glucose carriers located in the cell membrane transport glucose into the cell in the presence of insulin. Without insulin, only trace quantities of glucose enter the cell, explaining why diabetics must inject insulin for proper cellular function. Additionally, the presence of insulin in the muscle cells increases enzyme activity, thereby facilitating heightened protein synthesis. Therefore, insulin is anabolic both in its effect on the uptake of glucose in lipid and muscle cells, as well as through the promotion of protein synthesis (58).

**Thyroid Hormones**

The thyroid gland secretes two similar thyroid hormones, thyroxine (T4) and tri-iodothyroxine (T3). T3 is the active form of thyroid hormone (formed from T4) and acts to increase the metabolic rate of all cells (1). High level thyroid activity increases body temperature. T3 serves a permissive role, aiding in the development of lean mass. It does so by facilitating the actions of anabolic hormones and stimulating an increased secretion of GH in the pituitary gland and IGF-1 by the liver. During heavy exercise, thyroxine increases by about 35% (10). This elevation possibly contributes to immediate short-term excess post-exercise oxygen consumption through an increase in the resting metabolic rate of cells, thereby possibly adding to the effect exercise has on weight loss through heightened metabolic activity and increased use of fatty acids for fuel (31; 46; 47).

**Adrenal Hormones**

The adrenal glands produce two categories of hormones, neural and steroid. Neural and steroid hormones are made in different parts of the adrenal gland. Steroidal hormones are secreted from the adrenal cortex, and the neural catecholamines are produced in the adrenal medulla. The pituitary gland secretes adrenocorticotropic (ACTH) which stimulates the adrenal cortex to secrete adrenocortical hormones. These hormones serve functions such as the regulation of electrolytes and the production of cortisol and
androgens. The adrenal medulla is stimulated through neural pathways originating in the brain, which provide a more rapid response, producing the catecholamines epinephrine and norepinephrine. As part of the sympathetic nervous system, the adrenal medulla is responsible for augmenting neural effects.

The adrenal hormones are very important to exercise as they are specifically designed to manage stress (44). Aldosterone plays a key role in regulating ion activity and water balance by reabsorbing or excreting sodium. Aldosterone also contributes to the maintenance of proper mineral balance, which is important for nerve transmission and subsequent motor function. Cortisol is another adrenocortical hormone that contributes to physical activity by way of glucose metabolism and the preservation of storage reserve (43). Cortisol is viewed as a catabolic hormone due to the fact that its presence results in the breakdown of muscle tissue. It does so by increasing proteolytic enzymes, converting amino acids to glucose, and inhibiting protein synthesis in a process to spare glucose in the body. Cortisol inhibits carbohydrate uptake and oxidation in the body by acting as an insulin antagonist (22). In cases of high psychological stress, cortisol is continually produced, leading to significant protein breakdown, thereby causing muscle wasting and a negative nitrogen balance. Additionally, sustained high levels of cortisol can suppress the immune function, making one more susceptible to infection (21). This explains how psychological stress inhibits the immune function (42).

The body has a natural defense against the catabolic effects of cortisol. Testosterone can block the genetic element in DNA from cortisol, or insulin can bind in greater numbers to receptors, trumping cortisol’s effects on the protein (13; 62). The hormones that dominate the anabolic/catabolic balance determine which gets to apply its will upon the tissue (25; 27).

The hormones of the adrenal medulla are non-steroidal and work rapidly, through neural expression, on force outputs. Epinephrine and norepinephrine serve numerous functions, but in the muscle, they generally serve four categorical functions:

1) Neural, through central motor stimulation
2) Muscular, through enhancement to the enzyme systems of the tissue
3) Vascular, through vasodilation
4) Hormonal, through the augmentation of anabolic hormones

~Key Terms~

**Hypertrophy**- The increase in the size of an organ due to an increase in cell size. It is most commonly seen in muscle that has been actively stimulated, the most well-known method being exercise.

**Androgenic Hormone**- A steroid hormone, such as testosterone or androsterone, that controls the development and maintenance of masculine characteristics.

**DHEA**- Dehydroepiandrosterone is a natural steroid hormone produced from cholesterol by the adrenal glands.

**Androstenediol**- An unsaturated steroidal derivative of androstene.

**Androstenedione**- An unsaturated androgenic steroid that has a weaker biological potency than testosterone.

**Gynecomastia**- Overdevelopment of the mammary glands in males; male breast development.

**Insulin**- A natural hormone made by the pancreas that helps control the level of glucose in the blood.

**Glucagon**- A hormone produced by the pancreas that stimulates an increase in blood sugar levels, opposing the action of insulin.

**Catecholamines**- Any naturally occurring amine, functioning as a neurotransmitter or hormone, including dopamine, norepinephrine, and epinephrine.

**Adrenocortical hormones**- Any of the various hormones secreted by the adrenal cortex, especially cortisol, aldosterone, and corticosterone.

**Nitrogen Balance**- The difference between the amount of nitrogen taken into the body and the amount excreted.
The release of catecholamines is based on the acute stress experienced by the body. As with the other adrenal hormones, prolonged stress leads to reduced return or detrimental outcomes (16). The adrenal gland is tied very tightly to all components of training and recovery, including immuno-related activity (15; 64). This suggests that training needs to be dose-appropriate and balanced with other perceived stresses in the body to insure positive adaptive outcomes.

### Endocrine System

<table>
<thead>
<tr>
<th>Endocrine Gland</th>
<th>Hormone</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior Pituitary</td>
<td>Growth Hormone</td>
<td>Stimulates IGF, protein synthesis, growth and metabolism</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Thryoxine</td>
<td>Stimulates metabolic rate, regulates cell growth and activity</td>
</tr>
<tr>
<td>Adrenal Cortex</td>
<td>Cortisol</td>
<td>Promotes use of fatty acids and protein catabolism; conserves sugar; maintains blood glucose level</td>
</tr>
<tr>
<td></td>
<td>Aldosterone</td>
<td>Promotes sodium, potassium metabolism and water retention</td>
</tr>
<tr>
<td>Adrenal Medulla</td>
<td>Epinephrine</td>
<td>Increases cardiac output; increases glycogen catabolism and fatty acid release</td>
</tr>
<tr>
<td></td>
<td>Norepinephrine</td>
<td>Has properties of epinephrine and constricts blood vessels</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Promotes glucose uptake by the cell, stores glycogen; aids in protein synthesis</td>
</tr>
<tr>
<td></td>
<td>Glucagon</td>
<td>Releases sugar from the liver into circulation</td>
</tr>
<tr>
<td>Liver</td>
<td>Insulin-like Growth Factors</td>
<td>Increase protein synthesis</td>
</tr>
<tr>
<td>Ovaries</td>
<td>Estrogen</td>
<td>Stimulates bone remodeling activity; female sex hormone</td>
</tr>
<tr>
<td>Testes</td>
<td>Testosterone</td>
<td>Stimulates growth; increases protein anabolism; reduces body fat; male sex hormone</td>
</tr>
</tbody>
</table>

### Hormone Considerations for Training

As the intensity of the training regimen increases, the changes in both the muscular system and endocrine system become more apparent (26; 59). Although a great deal of attention is paid to the cellular activities in the target tissue, it is important to note that the hormones that most often dictate these adaptations also experience improvement in their function in response to the training. The adaptive process within the tissue and glands is a positive feedback loop. The tissues become
more efficient as disruptive environments force them to improve in efficiency; consequently changes in the tissue in response to the stress augment the hormonal effect and the glands that secrete them.

Endocrine adaptations are simply improvements in the actions they already perform. For instance, the glands increase the amount of hormones they produce and store. Obviously a greater concentration and secretion of hormones would suggest increased activity in the tissues they act upon. The hormones themselves do not change, but their concentration and effectiveness does. This occurs because more hormones can be transported; larger quantities are sustained in the system for longer periods of time; receptors increase in numbers and sensitivity, causing the magnitude of the signal to be enhanced; and finally, the tissue interactions increase for a more dynamic adaptation response.

The type of training one engages in, and the intensity at which it is performed, dictates the specific response by both the working tissue and the endocrine glands that mediate their actions (36). This is not only true between aerobic and anaerobic training, but also between training techniques within a particular category of training. Simply stated, the type of training one performs dictates the type and level of the hormonal response. For instance, resistance training can be performed for increased force and power output with very little change to the size of the muscle (36). This is due to the fact that tissue adaptations are most influenced by the circulating hormonal levels. As a personal trainer, it is important to understand that exercise prescriptions should be aimed at stimulating specific hormone activity related to the desired adaptation effect.

Identifying what each hormone does and what causes the respective gland or tissue to release it is integral in prescribing exercise designed to harness the desired outcome of the hormone. Due to the fact that muscle tissue is most responsible for physical action, it is noteworthy to analyze its relationship with hormones and the respective training responses. Muscle adaptations are generally viewed as metabolic changes or anatomical changes. The latter suggests that the tissue actually changes in structure. The positive adaptation process that occurs in muscle protein is called muscle remodeling. When the tissue experiences significant physiological stress the consequent disruption and damage to the muscle cell stimulates an inflammatory response (48). The specific method by which the physiological disruption occurs determines the extent of remodeling from neural, hormonal, and immune system influence (53). The hormonal interaction of GH, testosterone, IGF, T3, and insulin cause the cell to synthesize new protein structures along the sarcomere (51). Starting at the genetic level, cellular stimulation by hormone interactions initiates the action by which the muscle cells lay down new proteins (36). The contractile proteins, actin and myosin and the structural non-contractile proteins all experience protein enhancements, leading to greater size and strength of the tissue. Type II fibers experience a far more dramatic effect in protein synthesis than Type I fibers, which is why they are most often associated with muscle hypertrophy. But the abundance of Type I fibers distributed throughout the muscular system still plays a key role in muscle mass augmentation. Although limited protein synthesis occurs, Type I fibers experience a reduced degradation effect from hormone mediation. This combination of protein synthesis and reduced protein metabolism leads to noticeable gains in muscle tissue over time.

Hormonal Interaction and Exercise
When the motor neurons are activated, the stimuli to the brain cause a reactive communication to the endocrine system to secrete the appropriate hormones to manage the situation. As previously mentioned, the acute hormonal, neural, and immune messengers stimulated from physiological stress and consequent cellular disruption direct hormonal activity specific to the type of stress experienced (48). Therefore, the type of response one experiences from muscular endurance training is different from the response elicited by muscular power training, which is, in turn different than that from aerobic training. Each type of stress and the way the stress is applied has specific communications to how the body should manage the internal environment during and after an exercise session. The neural patterns activate hormonal patterns which shape the adaptive response to the training. Because the physiological environments are consistent in response to the stress of a particular nature, outcomes are very predictable based upon the exercise engaged in, and the intensity, rest interval, and duration employed.

Strength training utilizes heavy resistance loading and near maximal recovery periods (2-5 minutes) between sets with repetition ranges often less than eight. This formula makes the hormone activity very predictive. The training causes an increase in the anabolic hormones, but because the rest periods allow for so much recovery in the tissue and the stimulus is applied for only a short period of time, far less hypertrophic effects are noticed (36). This is explained by acute increases in testosterone without the more notable increases in GH. Recall that IGF, produced by GH influences, is the key protein synthesizer (52).
Therefore, activities that do not encourage the full hormone matrix responsible for muscle remodeling will not significantly increase muscle mass. The testosterone and neural factors contribute to increased force output with less protein synthesis due to a lower concentration of GH (36). It should be noted that heavy cross-joint lifts including squats and deadlifts have the most dramatic effect on circulating testosterone levels in heavy strength training programs.

**Resistance Training & Hormone Response**

**Effects on Hypertrophy**

When the training stress is modified so that the volume is high (3-4 sets), the resistance is moderately heavy (70-85% of 1RM), and performed for longer durations (8-12 repetitions) with short, one-minute rest periods, the serum concentrations of GH increase dramatically (36). Classically considered bodybuilding, the collective activity utilizes all the reactive stimuli for muscle growth. Conversely, lower repetition schemes (<8 repetitions) with heavy weight do not stimulate the body in the same manner, so less hypertrophy is experienced. Two notable factors to consider with hypertrophy training are blood lactate and cortisol levels (55). Although both products are considered detrimental to muscle protein in their respective activity, there is a definite link between the stress that causes their presence and the response of the pituitary gland. It is suggested that the body manages cortisol activity differently in high-demand-resistance-stress environments compared to other stress stimuli by blunting its negative effects (63). High productions of lactic acid with concurrent cortisol released by the adrenal glands in response to high intensity, extended-time-under-tension exercise stimulate greater GH release (36). The higher concentrations of GH released in response to the training stimulates IGF-1 release from the liver adding to the anabolic effects (36). Since high-volume, short-rest periods stimulate both cortisol release and higher concentrations of lactic acid in the blood, but heavy resistance training with low repetition schemes and long rest periods does not, it explains why the heavy strength training causes far less effect on GH and hypertrophy compared to the bodybuilding approach. The most common errors in bodybuilding or activities aimed at hypertrophy are lifting too light, not properly applying high volume isolative overload, and taking too long a rest period between sets and exercises, all of which consequently reduce the magnitude of the hormonal response.

**Effects on Aerobic Fitness**

Endurance training has a different hormone product response than that experienced during resistance training (60). This is, in part, due to the common employment of steady-state, continuously-applied activities that utilize the repeated action of certain muscle groups. Hormone activity seems to be sensitive to variations of intensity, so when the intensity is sustained, a lower hormone response is observed (60; 61). As would be expected from the previous reading, GH released in response to the endurance activities depends upon intensity (57). High intensity training, particularly that done above lactate threshold, shows the greater increase in GH compared to lower intensity markers (18). Testosterone seems to be suppressed during high intensity aerobic activities, but plasma levels will increase during moderate levels of endurance training (12). Testosterone production during aerobic activities is less when compared to anaerobic exercise at similar intensities. Insulin sensitivity is heightened and glucagon levels will increase slightly as exercise becomes more prolonged (11; 54). Catecholamines seem to remain relatively stabilized, but cortisol will slightly increase. In long endurance bouts, such as running a marathon, cortisol production will increase, as will the release of protein from muscle to promote carbohydrate sparing and help maintain energy stores (32). Due to the limited anabolic hormone activity, endurance training has minimal effect on muscle mass gain and actually will decrease lean mass in high volume programs due to catabolic effects (33).
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