

# Exercise and Stress Part II— The Stress Response

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## Introduction

The stress response works to activate the system, in preparation for a perceived or experienced threat to homeostasis. This activation entails increasing numerous hormones which elicit an effect on the body. In this context, the purpose of this paper was to discuss the stress response (the following paragraphs are based on the work of Inouye, 2006; Marieb, 2004; McEwen, 2002; Plowman & Smith, 2003; for more information, refer to those references.)

## The Stress Response

Hormones are signaling molecules, which regulate and coordinate physiological and metabolic functions by acting on receptors located on, or in, target cells. The study of hormones and endocrine glands is called Endocrinology.

Hormones can reach cells through 3 pathways. First, by circulation through the blood stream (endocrine); second, they can be released into interstitial fluid (the fluid between cells) and act on adjacent cells (paracrine); and third, they can be released into interstitial fluid, and act on itself (autocrine). Hormones can also use a combination of these three pathways to effect target organs.

Evidence suggests that there is a close link between the endocrine and nervous system. Thus, these systems are often collectively referred to as the neuro-endocrine system. Of particular interest to this paper is the autonomic nervous system.

The autonomic nervous system is a system of motor neurons that innervates smooth and cardiac muscles, and glands. It can be divided into two components: the parasympathic (PNS) and sympathetic nervous system (SNS).

Table 1.

*Functions of the Sympathetic Nervous System (Adapted from Inouye, 2006)*

Organ	Sympathetic Effects
Heart	Increased rate and contraction force
<b>Blood vessels</b>	
Coronary	Vasodilatation
Skin Surface	Vasoconstriction
Deep Muscle	Vasodilatation
Abdomen	Vasoconstriction
Blood coagulation	Increased
Blood glucose	Increased
Blood Pressure	Increased
Bronchioles in Lungs	Dilated
Gut	Decreased motility and blood flow; contractions inhibited
Pupils	Dilated
Piloerectors	Increased
Adrenal Medulla secretion	Increased

Table 1 lists the functions of the sympathetic nervous system. The SNS acts to release energy, and increases heart rate and breathing. It constricts visceral blood vessels (which include organs such as the stomach), and diverts blood to skeletal muscle and the heart. The PNS, often referred to as the rest and digest system, is mostly antagonistic to the SNS, and acts to conserve energy, keep blood pressure, heart rate, and respiratory rate (breathing) low, and diverts blood towards the stomach to digest food.

Blood pressure is a product of cardiac output \* total peripheral resistance. Cardiac output is a product of stroke volume \* heart rate. Stroke volume is how much blood is pumped out of the heart per beat; heart rate is how many times your heart beats per minute. Thus, factors which increase heart rate, or how much blood your heart pumps per minute (for example, increasing the contractility force of cardiac muscle, or blood volume) have the effect of increasing blood pressure. Peripheral resistance refers to the diameter of blood vessels. Constricting (narrowing) blood vessels has the result of increasing blood pressure; while dilating (widening) blood vessels has the result of lowering blood pressure.

Stress activates the SNS. This is commonly referred to as the fight or flight response. The hypothalamus—which is a part of the SNS—is the primary regulator of

the flight or fight response. The hypothalamus has control over the entire endocrine system. It releases tropic hormones, which are hormones that act to release another hormone, starting a hormonal cascade. There is a close interaction between the hypothalamus and pituitary glands.

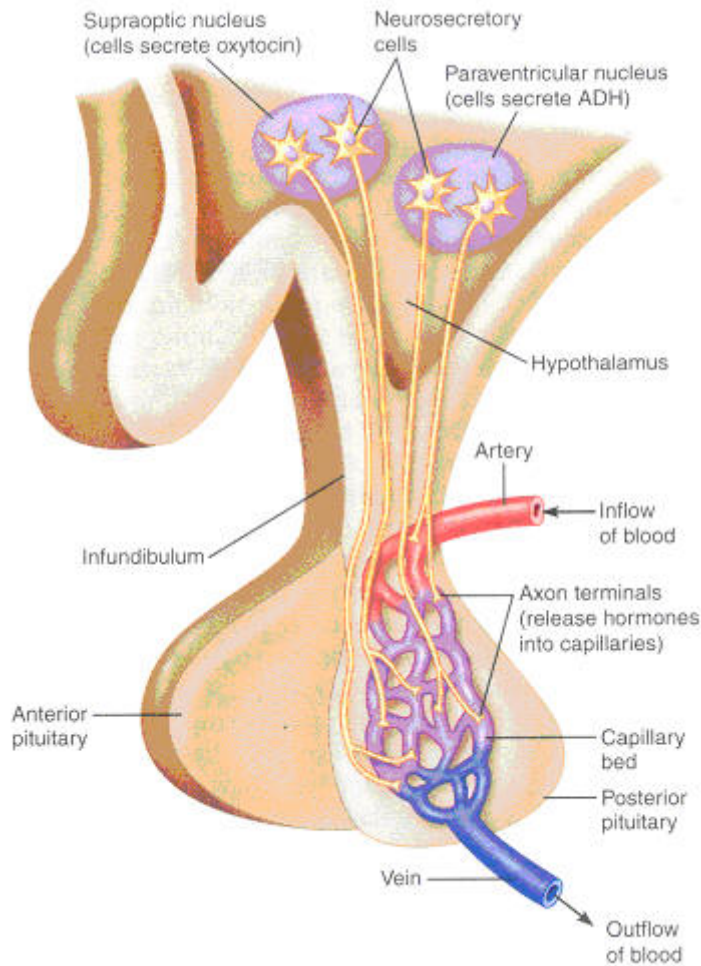


Figure 1.

*The Hypothalamic-Pituitary Axis.*

Figure 1 graphically depicts the interaction between the hypothalamus and pituitary glands. The hypothalamus is connected to the posterior pituitary, and sends nerve impulses which stimulate the release of hormones. The hypothalamus is connected to the anterior pituitary by the hypothalamic-pituitary portal system. A portal system is a specialized arrangement of blood vessels with two capillary beds located in series one after the other. And capillaries are thin blood vessels, where gas and nutrient exchange take place. This system ensures direct delivery of hormones to target cells, without diluting or degrading the hormones.

These structures stimulate various hormones; however, this paper will focus solely on those involved in the stress response.

Table 2.

*Hormones involved in the Stress Response*

Hormones	Actions	Blood Glucose	Blood Pressure
Cortisol	Gluconeogenesis and deamination of proteins; spares carbohydrates; suppresses inflammation	Up	X
Aldosterone	Increases sodium absorption, which increases water retention	X	Up
Vasopressin	Increases Water retention; vasoconstrictor	X	Up
Thyroid Hormones	Elevates metabolism, respiration, temperature, oxygen consumption, gastrointestinal motility, and cerebation	Up	X
Catecholamines	Liberates nutrient stores for fuel; increases heart rate and contractility, respiration, and perspiration	Up	Up

Table 2 lists the various hormones involved in the stress response and their actions

First, the sympathetic nervous system directly innervates organs; therefore, its effects are immediate. For instance, it has nerve endings on the heart, which act to accelerate cardiac muscle contractions. Thus, the immediate excitement you feel during a stressful situation, such as seeing a deer in the middle of the road when driving 60 miles per hour on a one way street, is caused by the sympathetic nervous system. The nerve endings of the sympathetic nervous system secrete the catecholamines norepinephrine and epinephrine; the SNS also stimulates the adrenal medulla to release catecholamines. However, the response of the adrenal medulla is delayed 10 times longer than the sympathetic nervous system (Inouye, 2006). The sympathetic nervous system also causes piloerection (stimulates the hair to stand up; presumably to scare predators), dilates the pupils (increasing the size of your eyes), and increases concentrations in the plasma of the protein fibrinogen, which is a key component to blood coagulation (blood clotting).

The hypothalamus starts a hormonal cascade during the stress response. The release of corticotropin releasing hormone from the hypothalamus triggers the release of adrenocorticotrophic hormone (ACTH) from the anterior pituitary, which triggers the adrenal cortex to release glucocorticoids and mineralcorticoids, the primary ones being cortisol and aldosterone, respectively.

To review, the adrenal gland is located directly above the kidneys. They house two hormonal centers: the adrenal medulla and adrenal cortex. The adrenal medulla is the core of the adrenal glands, and secretes catecholamines, 80% of which is

epinephrine, which has a more potent effect on the cardiovascular system; and the remaining coming from norepinephrine, which has a more potent effect on the vascular system. The adrenal cortex (cortex means “crust”) is the outer portion of the adrenal gland, and is composed of three zones—the current investigation is principally concerned with zones one and two. Zone one, called the zona glomerulosa, releases mineralcorticoids, which regulate the mineral salts sodium and potassium in the extra cellular fluid (fluid outside of the cells). Aldosterone is the most abundant mineralcorticoid, representing 95% of its class. Zone 2, called the zona fasciculate, secretes glucocorticoid hormones, primarily cortisol.

The hypothalamus also releases thyrotropin releasing factor, which triggers the anterior pituitary to release thyroid stimulating hormone (TSH; or TTH, which stands for thyroid tropic hormone), which triggers the thyroid gland—which resembles the shape of a butterfly, and is located in the neck—to secrete two hormones: triiodothyronine (T3) and thyroxine (T4), T3 being the most active hormone.

Further, the hypothalamus produces the hormone vasopression, also known as anti-diuretic hormone (ADH). ADH is packaged and transported to the posterior pituitary for storage. Then, during times of stress, the hypothalamus stimulates its release through nerve impulses sent to the posterior pituitary.

### **Actions of these hormones**

Cortisol is a hyperglycemic, or counter regulatory hormone, meaning that it raises blood glucose. Its actions include shifting substrate utilization away from carbohydrates and towards fats and proteins. Cortisol stimulates gluconeogenesis (the conversion of non-carbohydrate substrates to carbohydrates), typically of proteins, as well as deamination of amino acids by the liver (this involves removing the nitrogen group of the amino acid, and then using the remaining molecule for energy). Further, it suppresses the inflammatory response through degradation of white blood cells. For more information on cortisol, refer to [Slow Acting Hormones and their Role in Fuel use during Exercise.](#)

Collectively, catecholamines act to increase blood pressure, blood glucose, heart rate, respiration, and perspiration. For a more thorough discussion on the actions of catecholamines, refer to [Exercise Endocrinology Principles and Catecholamines.](#)

Thyroid hormones elevates metabolism, respiratory rates, internal temperatures, oxygen consumption, gastrointestinal motility, and cerebration (thoughts). For more information on thyroid hormones refer to [Slow Acting Hormones and their Role in Fuel use during Exercise.](#)

Vasopressin acts on the kidney to retain water, which increases blood volume; it also is a powerful vasoconstrictor (narrows blood vessel diameter). All of this results in higher blood pressure.

Aldosterone acts on the kidneys to reserve sodium, which further has the effect of reserving water. This also results in increased blood pressure.

### **Summary**

Stress stimulates the flight of fight response. Through the hypothalamus, SNS, anterior pituitary, and adrenal gland, stress triggers the release of various hormones that have the effect of increasing heart rate, blood volume, blood pressure, energy liberation for fuel, and many other effects all of which prepare the organism for action. The problems associated with the stress response will be discussed later on during this series. To continue on to part 3, click [Here](#).

Keep it Hardcore,

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## References

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