

Physiological Adjustments to Exercise

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Introduction:

The heart muscle is the source of physical strength and vitality in the body. It works together with the lungs and vascular system to provide the propulsion behind the blood's circulation. Other organs of the body, such as the kidneys, liver, brain and nervous system, contribute to the smooth functioning of the cardiovascular system by regulating the pulse, adjusting the pace, and making corrections in the rhythms of the heart. The typical pulse is 72 beats per minute in an adult individual at rest. Devotedly, the heart beats an average of 100,000 times in a day. However, the heart rate and rhythm varies from subject to subject and from activity to activity (Topol, 2000).

Variation in heart rate and rhythm between subjects is due to the fact that it is the heart's responsibility to regulate and maintain the transport of oxygen to the muscles and tissues of the body according to its needs at a particular time; the heart naturally pulses slower at rest and increases its pace during exercise or strenuous activity. Yet, there are many other factors that affect heart rate within the body, such as pain, emotional stress, and hormonal changes. The body's organs work together to allow the subject to properly function in a constant optimal state of homeostasis, and therefore, a factor affecting one organ most likely affects another, if not many others within the body (Topol, 2000).

The heart beat is controlled by electrical impulses that are generated at the sinus node, also known as the body's natural pacemaker. This electrical system to which the heart beats on generates wavelike movements within the myocardium causing rhythmic contractions, known as the heart beat or pulse. This heart beat has two phases; the diastole phase, which is when the heart relaxes and the cavities fill with blood as it dilates, and the systole phase, which is when the heart muscle contracts and surges blood into the aorta and the pulmonary artery (Topol, 2000).

The pressure on the walls of the arteries during these two phases is measured and recorded as the blood pressure. The measurements are recorded in fraction form as the systolic number over the diastolic number; the systolic number being the amount of pressure in the arteries during the systole phase, and the diastolic number being the amount of pressure in the arteries during the diastole phase. The ideal adult blood pressure is 120/80 mmHg or less, but this number may be altered throughout a daily day depending on if the body is exerting itself or is at rest (Sheps, 1999).

Blood pressure is monitored by the kidneys, liver, brain and nervous system. The kidneys remove excess water, electrolytes, sodium, and potassium from the blood. If the blood pressure should begin to fall, the kidneys release rennin, an enzyme that generates a series of events that result in a rise in blood pressure, to increase the blood pressure and cease this release when the blood pressure is too high. The functions of the liver in the body includes metabolizing energy, maintaining the level of iron in the blood, and filtering the blood of any harmful substances; all three major functions allowing the smooth flow of blood through the cardiovascular system (Topol, 2000). Blood pressure can also be negatively affected by external factors on the body such as poor diet leading to obesity and high cholesterol, inactivity, stress, and smoking. These factors can drastically raise blood pressure levels, and lead to: atherosclerosis, an accumulation

of plaque in the lining of the artery walls, arteriosclerosis, the hardening of the arteries, an aneurysm, when a blood vessel loses elasticity and bulges causing life-threatening bleeding, and/or heart failure (Sheps, 1999).

The pace of the cycle of electrical pulses of the heart is cued by messages from the brain, and can be influenced by conditions such as outside temperature, level of activity, pain, and emotional stress. The brain and nervous system maintain this communication through the use of neurotransmitters. The nervous system regulates heart and blood pressure, keeps the chemical composition of the blood in balance, and helps the cardiovascular system stay responsive to internal and external environments. An example of this homeostatic regulation includes the release of the hormones norepinephrine and epinephrine to signal the heart to quicken its pace for the fight or flight response, and the release of the hormone acetylcholine to reverse the fight or flight response. Another example includes the brain's respiratory center sending a message to speed up breathing in order to deliver more oxygen to the lungs and the blood during exercise (Topol, 2000).

In this experiment, heart rate and blood pressure was tested under different circumstances in order to explicitly view the effects that external factors play on the heart, and how it performs in different situations. In the first part of the experiment, a subject was tested for pulse and blood pressure in two different postures: reclining and standing. The hypothesis for this experiment is that body posture will affect pulse rate and blood pressure. The prediction is that standing position will have a higher pulse than the reclining position, and the standing position will increase the systolic and diastolic blood pressure numbers in comparison to reclining. The second part of the laboratory experiment was to test how high a subject's heart rate will increase immediately after exercise, as well as the rate as time passes after exercise. The hypothesis is that

the amount of time a pulse is taken after exercise affects the pulse rate until resting pulse rate is restored via homeostatic processes. The prediction is that the more time that passes before taking the pulse after exercise, the more the pulse rate will decline until the resting pulse rate is re-established.

The cardiovascular system interacts with several various organ systems within the body constantly in order to keep the organism alive. The connection and communication between the organ systems allows for homeostasis to occur and the body to be kept in the physiological range of efficient survival. Since there are so many interconnections and regulations between the organs of the body, there are also many disruptions that can contort the homeostatic state of the body, whether it is an internal or external factor. The internal factors include hormonal changes or imbalances, temperature, disease, and deficiencies or excesses of nutrients, salts, and electrolytes. The external factors include climate temperature, smoking, emotional stress, and exercise (Topol, 2000).

Results:

Figure 1: Physiological Adjustments to Exercise and Body Positioning

<u>Type of Test</u>	<u>Pulse (beats/minute)</u>	<u>Systolic/Diastolic Blood Pressure (mmHg)</u>
Reclining:	68	118/78
Standing:	72	127/79
Increase in pulse rate upon standing (standing-reclining):	4	-

Figure 2: Pulse Recovery of the Body over Time after the Harvard Step-Up Test

Figure 3: Personal History of the Harvard Step-Up Test Subject

<u>Area of Personal Information:</u>	-
Age:	20
Sex:	Female
Amount of sleep:	5 hours
Amount of smoking:	None
Kind of work usually done:	Walking and Cleaning; Moderately Active
Time since last meal:	1 hour
Personal Worries:	School Work and Family
Other pertinent information:	-

Conclusions:

1. Body posture influences pulse rate and blood pressure.

2. The pulse rate after exercise is influenced by the amount of passing time until resting pulse rate is restored.

Discussion:

Exercise offers many benefits to the human body; yet, it is important to understand how the heart and other organ systems in the body react to and affect each other during and after this physical activity; in order to ensure that the body is equipped to undergo physical stress. In this laboratory experiment, the pulse of a subject's heart was recorded and viewed in two different aspects under different factors. The first approach was testing the subject's pulse at rest standing and reclining. The purpose of these tests was to analyze the heart rate at rest in two extreme opposite positions, standing straight upright and lying flat down. The hypothesis of this experiment proved to be true because body position did affect pulse, as well blood pressure. According to figure 1, the pulse rate and blood pressure of the subject was slightly higher in the standing position and lower in the reclining position. This fact proves correct the original

prediction because standing did increase the pulse rate and blood pressure in comparison to reclining. The main point of this trial comparison was to show that even the slight exertion of having the body stand upright rather than recline laying down slightly increased the pulse and blood pressure. Therefore, the change in body posture from reclining to standing must increase stress on the body's ability to pump blood to the heart and from the heart to the organs, so pulse rate and blood pressure slightly increases (Topol, 2000).

The second phase of the experiment was to test the pulse rate of a subject at different time intervals after five minutes of the Harvard Step-up cardio exercise, which consisted of stepping on a step at a rate of six complete steps up and down every 15 seconds for the five minutes. The heart rate was then determined immediately, one minute, two minutes, and three minutes after the exercise. The purpose of this experiment was to see how high the pulse of the heart would go during exercise, as well as how quickly it recovered as time passed after exercise to reach resting heart rate once again. The original hypothesis was proven correct because the amount of time the pulse was taken after exercise did affect the pulse rate number. The prediction was also proven true because, as seen in figure 2, the more time that passed before taking the pulse after exercise, the lower the pulse rate was. In both cases though, the results did not show the return to the original pulse rate, mainly due to the fact that the subject's heart most likely needed more time to slow the pulse before it could return to a resting rate. Therefore, if more time was given after exercise to record the pulse, the experiment would have been more accurate in showing how long it took the subject's heart to return to resting heart rate after exercise.

In order to further understand the processes that increase pulse rate, the nervous system in conjunction with the endocrine system must also be comprehended. There are two divisions of the nervous system: the sympathetic nervous system, which turns on the fight or flight response, and the parasympathetic nervous system, which promotes the relaxation response (Franklin, 2004). The afferent

nerves in both systems convey impulses from sensory organs, muscles, the circulatory system and all the organs of the body to the controlling centers in the medulla and hypothalamus. From these centers efferent impulses are conveyed to all parts of the body by the parasympathetic and sympathetic nerves. The autonomic nerves are responsible for inferring stimuli resulting in, for the most part, involuntary bodily adjustments such as the rate and depth of respiration, and the dilatation or constriction of the blood vessels (Streeten).

Hormones are the chemical messengers produced by endocrine glands, which travel through the bloodstream to accelerate or suppress metabolic functions. The primary area of the brain that deals with stress, emotion, and memory is its limbic system. Whenever a threat is thought of or perceived, the limbic system immediately responds via the autonomic nervous system, a complex network of endocrine glands that automatically regulate the body's metabolism. Although the sympathetic nervous system jumps into action immediately, it is very slow to shut down and allow the tranquilizing parasympathetic nervous system to re-stabilize a calming state to the body. Once the stress response has been activated, the system maintains the body within a state of readiness. Although stress usually has a negative connotation, an appropriate amount on the body is a healthy and necessary part of life (Franklin, 2004).

During the fight or flight process, there is a release of norepinephrine, one of the principal excitatory neurotransmitters. Norepinephrine is needed to create new memories and improves mood. Stress management is an important skill for individuals to learn in order for a certain degree of limited control over the sympathetic nervous system. This may require knowledge of techniques that work to activate a subject's relaxation response of the parasympathetic nervous system. Ohio State University researchers found by measuring salivary concentration of SIgA, a major immune factor, that stress from engaging in a memory task activated the immune system, whereas the stress from passively watching a violent video

weakened immunity. These results suggested that deadlines and challenges at work, even if seem like a negative stress at the time, could be a good thing that helps strengthen the body's defenses in the future. Exercise has an extremely similar reaction in the body, but the reactions happen gradually versus immediately in the fight or flight response. Exercise is a great way to release these chemicals and stress hormones without chronic over-secretion within the body, as in the fight or flight response (Franklin, 2004).

A researcher named Robert M. Sapolsky, has shown that sustained stress can damage the hippocampus, the part of the limbic brain which is central to learning and memory. This is due mainly to the glucocorticoids, a steroid hormone also called corticosteroids or cortisol, being secreted from the adrenal glands during stress. During a perceived threat, the adrenal glands immediately release adrenaline. If the threat is severe or still persists after a couple of minutes, the adrenals then release cortisol. Once in the brain, cortisol remains much longer than adrenaline, where it continues to affect brain cells. Cortisol also interferes with the function of neurotransmitters, the chemicals that the brain cells use to communicate with each other. Therefore, excessive cortisol can make it difficult to think and/or retrieve long-term memories (Franklin, 2004).

The sympathetic nervous system is even more automatic and only exceptionally susceptible to any voluntary control. External factors also play a role in the effects on the nervous system of the body (Streeten). A large part of the energy that the body generates during exercise is degraded to heat. All body tissues produce heat that can be used to maintain body core temperature. When heat production exceeds the body's heat loss, body temperature rises. Intense exercise may increase the metabolic energy expenditure 20 to 25 times over resting levels. No more than 25 percent of this energy is utilized for muscular movement, so the remainder is heat,

which the body must dissipate. Metabolic heat is transferred by convection from working muscles to the blood stream, and thence to the body's core. The body is able to respond to a heat load through a variety of physiologic mechanisms: sweat rate, body and skin blood flow shifts, cardiac output, respiratory rate, and a sensation of heat intensity (Environmental).

When the environmental temperature is raised, the increased temperature initiates several automatic responses. Thermal receptors convey stimuli to sympathetic control centers of the brain from which inhibitory messages travel along the sympathetic nerves to the blood vessels of the skin, resulting in dilatation of the cutaneous blood vessels and increasing the flow of blood to the surface of the body. Heat can thereby escape by radiation from the surface of the body. Dilatation of the blood vessels in this way tends to lower the blood pressure and to promote transudation of the fluid from the capillaries. The sympathetic nervous system responds to environmental heat in another important way. The rise in body temperature is sensed by the hypothalamic center from which stimuli originate via sympathetic nerves to the sweat glands, resulting in appropriate sweating. This serves to cool the body by the loss of heat resulting from evaporation of the sweat (Streeten).

In this experiment, the subject's personal history, as viewed in figure 3, can cause major effects on the heart rate during and after exercise. The subject is only moderately active, the body is not accustomed to daily strenuous activity, and the subject has some degree of personal stress in life that will also have an effect on heart rate. These two factors will enable the heart rate to go higher than a subject with less personal stress and more adaptability to exercise. This fact combined with the actual stress of the exercise will cause the nervous system to become aware of the stimuli, sending out hormones throughout the blood stream to increase levels of available energy by increasing heart rate. The heart will also be using more oxygen to work harder, so

pulse will therefore be increased so that more oxygen can reach the heart through the circulatory system in a shorter amount of time. The ability of the heart to then go slower and calm down after exercise shows how well the body can recreate homeostatic heart rate levels (Topol, 2000).

It is important for overall cardiovascular health to control and manipulate the body's environment in order to benefit the functioning of the heart and the other systems that work with it, such as the nervous and endocrine systems. Smoking, in addition to high cholesterol, high blood pressure, physical inactivity, obesity, and diabetes tops the list as a primary risk factor for cardiovascular disease, and will also have a negative effect on the subject's heart rate. In fact, smoking has been classified as the single most preventable cause of premature death in the United States. (Oregon, 2008) Whether it is external factors affecting the body's cardiovascular system like smoking or stress, internal factors that were caused by external factors such as high blood pressure or high cholesterol, or an internal factor such as hormonal changes, the heart will show both the positive and negative effects of these factors in its performance at rest and during exercise. It is important not only to have a normal resting pulse rate, but it is just as important to understand how well the heart can undergo strenuous physical activity and recover from that activity because this test of fitness exposes the heart for how strong it really is when it has to work its hardest. Making sure that the systems in connection with the cardiovascular system are efficiently helping to maintain homeostasis in the body, no matter what external or internal factors involved, is the true answer to the body's ability to effectively survive (Topol, 2000).

Questions:

1. What neural mechanisms are involved in the increase in pulse pressure and heart rate with exercise?

There are three mechanisms that play a role in cardiovascular neural regulation during exercise. In the first mechanism, activation of regions of the brain responsible for the skeletal muscle motor units needed for exercise, as well as the neuronal circuits within the medulla, establish activity that determines the cardiovascular responses during skeletal muscle contraction; this is called the Central Command. In the second mechanism, neural signals arising from stimulation of chemo-sensitive receptors in the contracting muscles activate the cardiovascular control areas in the medulla, being named

the exercise pressor reflex, or the muscle metaboreflex. The third mechanism involves the arterial baroreceptor reflex (Iellamo, 2001).

2. What hormonal factors are involved?

The SA node of the heart is innervated by both sympathetic and parasympathetic nerve fibers. Under conditions of rest the parasympathetic fibers release acetylcholine, which acts to slow the pacemaker potential of the SA node and thus reduce heart rate. Under conditions of physical or emotional activity sympathetic nerve fibers release norepinephrine, speeding up the pacemaker potential of the SA node thus increasing heart rate. Sympathetic nervous system activity also causes the release of epinephrine from the adrenal medulla. Epinephrine enters the blood stream, and is delivered to the heart where it binds with SA node receptors, leading to further increase in heart rate (Doohan, 1999).

3. What is the role of external and internal temperature during exercise?

External, or climatic, and internal, or metabolic, heat sources influence body temperature. Heavy exercise alters body temperature outside the normal range by producing excess metabolic heat. When this occurs, metabolic heat increases the thermal load and evaporation decreases the buildup through a continuous heat exchange between the body and the environment. The bi-directional routes for heat exchange are convection, conduction, and radiation. Metabolic heat can also be transferred by convection from working muscles to the blood stream, and then to the body's core. The body's internal temperature depends upon other factors such as sweat rate, body and skin blood flow shifts,

cardiac output, respiratory rate, and a sensation of heat intensity. The external temperature plays a role on the body due to the fact that greater the gradient between skin and environmental temperature, the greater the heat loss (Environmental).

4. What anatomical pathways may be involved when psychological problems affect heart rate and blood pressure?

The sympathetic nervous system does an excellent job of rapidly preparing the body to deal with what is perceived as a threat to safety. The sympathetic nerves reach their end-organs through pathways down the spinal cord to clusters of sympathetic nerve bodies called ganglia, which are alongside the spine where the messages are relayed to other neurons that travel to a large extent with the blood vessels to all parts of the body (Streeten). Its hormones initiate several metabolic processes that best allow the body to cope with sudden danger, called the fight or flight response. The adrenal glands release adrenaline (also known as epinephrine) and other hormones that increase breathing, heart rate, and blood pressure. This moves more oxygen-rich blood faster to the brain and to the muscles needed for fighting or fleeing. Adrenaline causes a rapid release of glucose and fatty acids into your bloodstream, increasing the available energy of the body. Other hormones shut down functions unnecessary during the emergency, such as growth, reproduction, and the immune system. Blood flow to the skin is also reduced, which is why chronic stress can lead to sexual dysfunction, increase the chances of getting sick, and can manifests as skin ailments (Franklin, 2004).

5. What is the relationship between the hypothalamus, the endocrine system and the autonomic nervous system during exercise?

The hypothalamus is found in the lower part of the brain in the midbrain where it functions in receiving messages from nerves and integrating that into endocrine gland responses. The hypothalamus is more or less the communication link between the nervous system and the endocrine system. The nervous and endocrine systems are related in three main areas, structure, chemical, and function. The endocrine and nervous system work parallel with each other and in conjunction function in maintaining homeostasis, development and reproduction. Both systems are the communication links of the body and aid the body's life systems to function correctly and in relation to each other.

Structurally many of the endocrine system's glands and tissues are rooted in the nervous system. Glands such as the hypothalamus and posterior pituitary are examples of nerve tissues that influence the function of a gland and its secretion of hormones. Not only does the hypothalamus secrete hormones into the bloodstream, but it regulates the release of hormones in the posterior pituitary gland. During exercise, the autonomic nervous system sends information from sensory neurons to the viscera of the central nervous system. In the autonomic nervous system, the central nervous system sends information through motor neurons to smooth muscles, cardiac muscles and glands. The autonomic nervous system is controlled by the hypothalamus and medulla oblongata of the brain, which regulate the smooth muscle, cardiac muscle, and specific glands (Bailey, Facey, Fitzgibbons, Koehler, Pouliot, Tatro, Wellens, Weeks).

6. How does smoking affect the cardiovascular system?

Smoking affects the cardiovascular system by causing immediate and long-term increases in blood pressure and heart rate, reduces cardiac output and coronary blood flow, reduces the amount of oxygen that reaches the body's tissues, and changes the properties of blood vessels

and blood cells, which allows cholesterol and other fatty substances to build up. It also contributes to an increased risk of blot clot formation due to higher blood pressure. The blood vessels become damaged, and this doubles the risk of ischemic stroke due to the reduced blood flow to the brain (Oregon, 2008).

7. How accurate do you consider the Harvard Step-up Test to be as an indicator of physical fitness? Explain.

The Harvard Step-Up test is an overall accurate test of physical fitness because it allows the subject to increase heart rate in a matter of minutes, and then record how fast the heart recovers from such a sudden surge in heart rate. The quicker the pulse slows the more in shape the subject is viewed to be. The true test of a healthy heart is how strong it is, and therefore, the stronger it is the quicker it will recover from cardio exercise. This is exactly what the Harvard Step-Up test records, and in less than ten minutes.

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