THE BASICS OF EXERCISE PHYSIOLOGY: IMPROVING WELLNESS THROUGH THE BENEFITS OF EXERCISE

5.7 Contact Hours

Written By: Trenton J. Niemi, MS

Course Objectives

Upon completion of this course the reader should be able to:

- Recognize basic principles of exercise physiology.
- Identify fundamental transient adaptations of different systems in response to exercise.
- Identify fundamental permanent benefits of different systems in response to exercise.
- Utilize the knowledge gained in the course to identify possible morbidity/mortality risks in individuals due to their response to exercise.
- Apply the principles of exercise physiology to prescribe exercises that prevent or decrease certain chronic conditions.
- Apply the principles of exercise physiology to prescribe exercises that allow a person to attain maximum results in pursuit of their goal.
INTRODUCTION

To maintain a healthy lifestyle, the importance of physical activity cannot be underestimated. It is the single most important endeavor that one can participate in to promote health throughout a lifetime. For decades, epidemiological research has accumulated highlighting the health benefits associated with regular physical activity. Furthermore, there is overwhelming research illustrating the morbid and mortal consequences of being sedentary. Benefits of a proper exercise regimen include:

1. Increase in the efficiency of cardiovascular and respiratory function
2. Reduction in coronary artery disease risk factors
   a. Reduction in blood pressure
   b. Increase in HDL and decreased triglycerides
   c. Reduction of body fat
   d. Reduced insulin needs, improved glucose tolerance
      • Decreased incidence of type II Diabetes
3. Decrease in mortality and morbidity
   a. Decreased incidence of Coronary/vascular disease
   b. Decreased chance of cancer
      • Breast
      • Prostate
      • Lung
      • Colon
   c. Decreased chance of osteoporosis
   d. Increased balance
      • Decreases incidence of falling
4. Decreased anxiety and depression
5. Enhanced performance of work, recreational, and sports activities
6. Enhanced feelings of well-being

Undoubtedly, results reaped from participating in regular physical activity are second only to those of the fountain of youth. It is the only lifestyle choice that not only adds years to one’s life, but adds life to one’s years.

Within the general population, the health benefits associated with increases in physical activity are potentially mammoth. Chronic diseases, their complications, and associated costs would be lowered drastically if our sedentary population simply became more active. Perhaps the most promising information regarding physical activity and health is the fact that the most significant health benefits of exercise are seen in those sedentary individuals who become moderately active. Furthermore, physical activity need not be vigorous to attain health benefits. This mounting epidemiological research is bringing about increasing momentum to promote regular physical activity as a means of preventative medicine.
The following course explores the basic physiological responses to exercises, both transient and permanent. It will examine the different systems of the body and how they are uniquely affected by exercise. Furthermore, the course goes on to explain how the healthcare professional may use this knowledge of exercise physiology to identify morbidity risks, treat certain chronic conditions, and maximize benefits brought about by regular physical activity.

The healthcare professional involved with exercise promotion or education should have a fundamental understanding of the dynamics involving exercise physiology. Insight of how our bodies physiologically respond to exercise and the ensuing benefits that result will help the professional in the matter of patient education. Armed with this knowledge they are not only better able to prescribe an appropriate activity, but allow the patient to experience maximized benefits.

**THE CARDIOVASCULAR SYSTEM**

Some of the most pronounced changes that occur at the beginning of exercise are seen in the cardiovascular system. Within the first few seconds after the onset of rigorous exercise there is a tremendous amount of increased demands placed on the body. It is obvious that most of this is demand is to provide working musculature the necessary blood flow to continue the activity. To prolong exercise, contracting muscles require an efficient delivery system as they require vast amounts of nutrients and oxygen while at the same time producing waste and heat needing to be discarded.

The changes that occur to the cardiovascular system during exercise all have a common function: they allow the body to meet the increasing needs demanded from an increased workload on the body. Many components of the cardiovascular system work in tandem with one another to achieve this goal. Like a fine tuned machine, the components of the cardiovascular system are orchestrated by local mechanisms as well as the neural and endocrine systems to supply the increase in demand. The control by the nervous and endocrine systems will be discussed in a later topic. To better understand the contribution of every mechanism, we will need to take a quick look at each in greater detail. The following physiologic factors perform a unique contribution to the overall goal of homeostasis. These will include:

- Heart Rate
- Stroke Volume
- Cardiac Output
- Blood flow
- Blood Pressure
- Blood Dynamics

**HEART RATE**

The typical resting heart rate is between 60-80 beats per minute (BPM). It is not uncommon, however, to see significant fluctuations in these normal values with relatively healthy individuals. For example, sedentary individuals may have a resting heart rate of over 100 BPM while some conditioned athletes may have rates lower than 40 BPM when they are at rest and relaxed. The efficiency of a trained heart is
responsible for the vast discrepancies between the ability to pump adequate amounts of blood at 100 BPM or 60 BPM. The heart of a trained individual has actually increased in size, both in musculature and chamber volume. This adaptation promotes the ejection of more blood with each beat.

The beginning of exercise triggers both the nervous and endocrine system to respond by influencing the beating frequency and force of contraction of the myocardium. In response to increases in workload heart rate rises in a predictable manner. The intensity of the particular exercise is able to be measured in total oxygen uptake as it is directly related to the workload. Total oxygen uptake is measured in liters per minute. This is accomplished by an apparatus that is placed on the subject allowing for a direct measurement of how much oxygen is being extracted by the tissues used for energy production to perform work (see Figure 1). As noted earlier there is a proportional increase in heart rate as workload increases. Although, in figure 1, one will notice that eventually the heart rate reaches it’s beating potential and fails to rise even though work load continues to increase. This is known as heart rate maximum. For each person this value may be different declining steadily with the aging process.

Statistically speaking the maximum heart rate is predictable based on a person’s age. Max heart rate decreases about one beat per year starting at roughly 10-15 years of age. To estimate maximum heart rate one would take the number 220 and subtract it from the person’s age.

Maximum Heart Rate Estimate:

\[ = 220 - \text{age} \]

STROKE VOLUME

The amount of blood that is ejected from the heart with each beat is known as stroke volume. The stroke volume is calculated by subtracting the volume of blood in the left ventricle at maximal volume by its minimal volume. A normal resting stroke volume is 82 +/- 20 ml. In other words, the heart of a resting individual ejects roughly 82 ml of blood into the aorta with each beat. Along with heart rate, stroke volume is able to dramatically increase with exercise. During rigorous activity, stroke volume may increase to 120 ml in the heart of an untrained individual. Trained athletes may attain maximal stroke volumes of up to 200 ml.

Figure 2 illustrates that stroke volume increase with a rise in workload. Notice that stroke volume increases are limited. Research has demonstrated that stroke volume will continue to increase up to about 40-60% of maximal workload.

The increase in stroke volume observed with increases in workloads is determined by factors such as:

![Stroke Volume Response to Workload](image)
1. Blood return to the heart
   a. Due to the Frank-Starling law of the heart, increases in blood volume entering the heart will result in increased volume of blood ejected.
   b. The capability of the heart tissue to distend accepting larger volumes of blood
2. The contractility of the myocardium
   a. An increase in myocardial distension results in an increase in contractility
3. Aortic and pulmonary pressure

**CARDIAC OUTPUT**

Cardiac output is defined as the amount of blood pumped out of the heart per unit of time. In other words, cardiac output (\( \dot{Q} \) = heart rate (HR) \( \times \) stroke volume (SV)). At rest in the normal individual, cardiac output is between 4-5 liters per minute. During exercise in untrained individuals it can rise to approximately 20 liters per minute, while some elite endurance athletes have been recorded to have cardiac outputs exceeding 35 liters per minute. It should not be surprising that cardiac output is directly related to workload. Like the previous figures, cardiac output rises as HR and SV increase. Depending on the individual, cardiac output may rise significantly, but will level off when the physiological limits of the heart have been met.

**DISTRIBUTION OF BLOOD FLOW**

It is not surprising that at the onset of exercise blood is redistributed throughout the circulatory system. Local, neural, and hormonal factors determine blood distribution throughout the body’s vasculature. During exercise these factors redistribute blood in a predictable fashion:

- Increased blood flow to the skin
- Helps to promote heat loss maintaining body temperature
- Increased blood flow to the working musculature
- Decreased visceral blood flow
- The redistribution of blood away from visceral organs allows more blood volume in active circulation
- Decreased renal blood flow
- Decreased filtration results in the preservation of blood volume
- Increased blood volume via “venous pool” return
- During rest roughly 60% of blood volume resides in the venous system. At the onset of exercise a large volume of blood is ejected from this venous pool into the active circulation. This is due to overall vasoconstriction in the venous system along with the activation of the skeletal muscle pump.
- Vasoconstriction of the spleen
- Increased blood volume in active circulation
**Blood Pressure**

Blood pressure (mmHg) is determined by multiplying the cardiac output by the total peripheral resistance. Total peripheral resistance is defined as the frictional resistance, or impedance to blood flow in the vascular system. Total peripheral resistance increases with overall vasoconstriction and decreases with overall vasodilation. Although there is abundant vasoconstriction during exercise in the vessels described above, peripheral resistance actually decreases due to the massive vasodilation of vessels supplying working skeletal muscle. This would lead one to believe that exercise causes blood pressure to go down. On the contrary, although there is an overall decrease in peripheral resistance, the increases in cardiac output are substantial enough to cause an overall increase in blood pressure. For example, at rest a normal individual has a cardiac output of 5 liters per minute. This can increase 400% to 20 liters per minute during maximum exercise. While at the same time, total peripheral resistance may have dropped to a third of resting values. An increase in blood pressure is vital during exercise as it acts to meet the supply of increasing demand on the musculoskeletal system.

The blood pressure dynamics during exercise are well established. In a linear fashion similar to heart rate, systolic blood pressure (SBP) rises steadily during exercise. Within certain parameters this is a desired effect. As stated previously the increase in blood pressure acts to meet an increasing demand. In a normal individual, SBP may rise from 120 mmHg during rest to greater than 250 mmHg. At the same time, little change is noted in diastolic pressure. Typically there is very little change or a drop less than 10 mmHg. At the cessation of the exercise bout, the SBP should drop back to normal values within a few minutes. See Figure 3.

When feasible, the monitoring of blood pressure during exercising can serve as an important diagnostic tool for the healthcare professional. For example, failure of SBP to increase despite an increase in workload suggests myocardial ischemia and or left ventricle dysfunction, whereas a significant increase in DBP (greater than 15 mmHg or above 110 mmHg) has been demonstrated to indicate the prevalence of coronary artery disease. Recall that the diastolic phase of myocardial contraction is of particular importance to coronary blood flow. During diastole the myocardium is at rest which allowing coronary arteries sufficient dilation for blood flow. Furthermore, maximal exercise SBP of 140 mmHg or lower suggests a poor prognosis of heart failure.

Patients with established risks for a coronary event should have their blood pressure and heart rate administered prior to and during the exercise bout (every 2 to 3 minutes), and at one to two minute intervals during the recovery period until heart rate and blood pressure have stabilized. Prior to exercise the assessment of blood pressure is as follows:
<table>
<thead>
<tr>
<th>Category</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal</td>
<td>&lt; 120 And &lt; 80</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>120-129 And 80-84</td>
<td></td>
</tr>
<tr>
<td>High Normal</td>
<td>130-139 Or 85-89</td>
<td></td>
</tr>
<tr>
<td><strong>Hypertension</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 1</td>
<td>140-159 Or 90-99</td>
<td></td>
</tr>
<tr>
<td>Stage 2</td>
<td>160-179 Or 100-109</td>
<td></td>
</tr>
<tr>
<td>Stage 3</td>
<td>&gt; or equal to 180Or &gt; or equal to 110</td>
<td></td>
</tr>
</tbody>
</table>

There is ongoing debate on a safe level of increase for both SBP and DBP during exercise. When deciding on a safe increase in blood pressure during a bout of exercise, the first consideration of the healthcare professional should be the individual undergoing the exercise. For example, an abnormally high SBP in a hypertensive should raise more concerns than that of the same reading in an elite athlete. According to the American College of Sports Medicine’s (ACSM) Guidelines for Exercise Testing and Prescription1, absolute and relative indications for terminating exercise have been established. They are as follows:

1. **Absolute**
   a. Drop in SBP of greater than or equal to 10 mmHg from baseline BP despite an increase in workload when accompanied by other evidence of ischemia
   b. Any decrease in SBP despite an increase in workload

2. **Relative**
   a. Drop in SBP of greater than or equal to 10 mmHg from baseline BP despite an increase in workload, in the absence of other evidence of ischemia
   b. A hypertensive response
      • SBP greater than 260
      • DBP greater than 115

**Hypertensives and Exercise**

As the blood pressure table indicates, a hypertensive is defined as an individual with a resting systolic blood pressure of 140 mmHg or a diastolic blood pressure of 90 mmHg, or currently using blood pressure medications. According to the American Heart Association, more than 50 million Americans are defined as being hypertensive. The incidence of high blood pressure increases dramatically with age and is more prevalent in men than women and more so in minorities such as Black and Hispanic populations compared to their Caucasian counterparts. All stages of hypertension especially the later two are associated with increased risk of cardiovascular events and or renal disease.
Decreasing morbidity or mortality utilizing the least invasive means possible is the obvious goal for maintaining blood pressure within normal limits. Along with other lifestyle modifications such as losing weight if overweight and smoking cessation, exercise has been useful in the treatment and the prevention of hypertension. According to ACSM, endurance training effectively lowers blood pressure parameters. It has been shown to elicit an average reduction of 10mmHg for both SBP and DBP in individuals with stage 1 or 2 essential hypertension. They recommend that exercise training be used as part of the initial treatment strategy to treat individuals with stage 1 or 2 hypertension. Furthermore exercise is recommended for patients on antihypertensive medications, as it elicits the same response of lowering BP allowing the patient to reduce medications. Finally, ACSM does not recommend a training regimen that utilizes resistance training as a primary exercise activity.

Although resistance training is important in an overall training regimen, it alone has not been proven to decrease or prevent elevations in resting blood pressure. Furthermore, caution should be used with resistance training and hypertensives. As it has been stated, resistance training can increase already elevated levels of blood pressure. It is also noteworthy to never use any overhead lifts such as a military press with hypertensives as these activities have been shown to exacerbate increases in elevated blood pressure.

**BLOOD PRESSURE DYNAMICS AND RESISTANCE TRAINING**

The blood pressure response during resistance training (weight lifting) is much more exaggerated than with aerobic type activities such as walking. During high intensity resistance training, systolic and diastolic blood pressures have been measured as high as 480/350 mmHg respectively with no ill effects. This surge in blood pressure is due partially to the fact that muscle contraction under enormous strain causes vasoconstriction within the muscles involved. This increases total peripheral resistance substantially. As you will recall, BP is a function of TPR. It should also be noted that during heavy resistance training the subject is inclined to perform what is known as a Valsalva maneuver. This is when a subject under strain will expire against a closed glottis not allowing the air out of the nose or mouth. The healthcare professional should be wary of this maneuver. The Valsalva maneuver may be dangerous as it increases intrathoracic pressure further exacerbating blood pressure and thus the workload of the heart. An effective method of avoiding the Valsalva maneuver during resistance training is to have the subject avoid holding her breath by continually breathing. More specifically, during resistance training events the subject should breathe out on effort. For example, if a subject is doing bicep curls, as they curl the weight up they should breathe out, whereas they should breathe in when lowering the weight down.

**BLOOD**

During exercise there is a shift of water from the plasma volume to intracellular and interstitial spaces, thus decreasing overall blood volume. There are three major reasons for this. First, sweating is induced which reduces blood plasma volume. Second, there is a buildup of metabolic byproducts in the muscle which increases its osmotic gradient, thus pulling water in. Third, as stated previously, blood pressure increases with exercise. The increase in pressure forces water into the interstitial spaces. As a result of these three mechanisms exercise can cause blood volume to drop as much as ten percent. This may impede performance as it will have a direct result on decreasing the amount of blood returning to the heart and thus stroke volume.

A benefit of endurance type training is that it has been demonstrated to increase overall blood volume. The increase in blood volume is due primarily to two mechanisms which increase plasma volume. As will be mentioned in the upcoming sections of this course, exercise induces the release of antidiuretic hormone and aldosterone which act to retain more water and thus blood volume. In addition, habitual endurance exercise training has been demonstrated to increase the osmotic gradient of blood by increasing plasma
proteins especially albumin. Therefore, activating these two mechanisms, endurance training increases the body's blood volume. These adaptations have been found to take place rather quickly as only a few days of endurance training may produce blood volume gains by almost 400 ml even in fit individuals.\(^4,5\) When comparing sedentary individuals to fit individuals blood volume may rise 20-25% from 5 liters to 6-7 liters respectively.

These studies\(^4,5\) have found that endurance training also increases red blood cell volume by a small percent. It should be noted that even though red blood cell volume may increase due to endurance training, relatively speaking, there is a much greater increase in the plasma portion of blood producing a lower hematocrit value. This is a desired effect as blood with a lower ratio of red blood cells to plasma is less viscous, facilitating greater blood flow throughout the vascular system.

**CARDIOVASCULAR DRIFT**

During exercise at a continuous exertion level such as walking at a steady pace, the heart rate should reach a “steady state” in which it does not fluctuate unless there is a change in workload. During prolonged exercise, however, the heart rate may increase despite a steady state workload. This phenomenon is known as cardiovascular drift. It is caused by a decrease in blood volume which is a result of fluid loss from excessive sweating. With decreased blood volume, stroke volume falls and HR will increase to compensate for the loss of SV. If the exercising individual fails to intake an adequate volume of fluids lost by sweating, cardiovascular drift will result.

**REVIEW OF CARDIOVASCULAR ADAPTATIONS TO TRAINING**

A number of permanent cardiovascular adaptations take place with exercise training. Some of the most important are the factors that increase the efficiency of the heart. Cardiac hypertrophy is a normal response to chronic endurance training. Like other muscles of the body the myocardium is able to respond to the stresses placed upon it. Endurance and resistance training have both been shown to increase the heart’s weight, volume, and chamber size. Studies have shown that the greatest change takes place in the myocardial wall thickness in the left ventricle.\(^6\) It would follow that permanent changes to the size and pumping capacity of the heart would have a direct effect on stroke volume. It is well established that after sufficient endurance training, the resting and exercising stroke volumes are significantly higher than that of pre-training values.

Another important factor contributing to increases in stroke volume is the volume of blood that reaches the heart. Because the heart can only pump out the blood that it receives, increases in the overall blood volume, and thus, the volume of blood returning to the heart has a direct effect on stroke volume.

Resting heart rate has been found to decrease significantly after endurance training. One may speculate that because cardiac output is a function of HR \(\times\) SV, resting heart rate in a trained individual is simply lower due to the increased efficiency of the heart. This is not entirely true. It seems that endurance
training influences the nervous system to lower the heart rate at rest. These mechanisms are not completely understood but it is believed to be partially due to a decrease in sympathetic and an increase in parasympathetic tone to the heart. Note that the definition of bradycardia is a heart rate of less than 60 beats per minute. Keep in mind that the heart of a well trained athlete may have a resting rate of less than 40 beats per minute. Therefore, it is important to differentiate between the trained individual in which a low resting heart rate is a normal response to training verses an untrained individual in which bradycardia may be an indicator of disease or abnormal function.

![Figure 4. Changes in Submaximal HR With Endurance Training]

Heart rates in endurance trained individuals are also slower during submaximal type activities. This is directly due to the increased efficiency of the heart. More volume ejected per beat results in less overall beats. Notice in figure 4 that after a 6 month moderate intensity endurance training program the subjects’ heart rate was lower that in pre training values.

THE RESPIRATORY SYSTEM

Like other systems of the body, the respiratory system is signaled to increase its productivity to meet the demands of an increasing workload. Recall that the process of cellular respiration requires a constant transport of oxygen to the cells, as well as a waste removal system. Although the cardiovascular system delivers oxygen to the cells and removes carbon dioxide, the respiratory system allows for the gas exchange with the outside environment. In a healthy person, these two systems work seamlessly to supply the cells of the body with their transportation needs.

When muscle cells begin contracting, the demand for oxygen and the production of carbon dioxide and lactic acid increase dramatically. Almost immediately the respiratory system responds to these increased demands. There are many different regulatory mechanisms that have influence over respiration. This complex system receives neural as well as chemical information regarding the state of the body. The respiratory centers that are located in the brain stem and are influenced by local chemoreceptors as well as peripheral chemoreceptors that are located in the carotid bodies and the aortic arch. These chemical receptors respond to changes in the blood’s pH and partial pressure of carbon dioxide and oxygen. In addition, the respiratory centers in the central nervous system receive neural input from limbs and musculature regarding movement of the body.

At the onset of exercise, an almost immediate increase in the depth of respiration occurs. At the same time, pulmonary vasculature dilates allowing a larger quantity of blood perfusion. This initial rise in respiration is due to neural input that senses movement of the body. As exercise continues the depth and
frequency of respiration is altered based on the environment of the blood. Respiratory stimulation is most sensitive to changes in the partial pressure of carbon dioxide. This is due to the fact that a build up of carbon dioxide impacts the acidity of blood. If the rate of respiration is not frequent enough it will result in a buildup of the partial pressure of carbon dioxide in the blood. This deviation can severely affect the pH of blood as increased levels of carbon dioxide will combine with water to form carbonic acid which can then release hydrogen ions (acid) into solution.

This reaction is illustrated in the following:

\[
\begin{align*}
\text{CO}_2 + \text{H}_2\text{O} & \rightarrow \text{H}_2\text{CO}_3 \\
\text{H}_2\text{CO}_3 & \rightarrow \text{HCO}_3^- + \text{H}^+
\end{align*}
\]

Therefore, an accumulation of carbon dioxide in the blood (caused by exercise or any other factor) will trigger the respiratory centers of the brain to increase the rate and or depth of respiration to blow off excess CO2. This action acts to maintain blood homeostasis by decreasing the partial pressure of carbon dioxide in the blood, and thus the acidity of the blood.

In a healthy individual, respiration is not a limiting factor for aerobic performance. In other words, the respiratory system can compensate for increases in workload better than the cardiovascular system. For example, in a healthy young male at rest the volume of air inspired or expired per minute is roughly 5 liters. At rest this healthy young male would have a cardiac output of 5 liters per minute. At maximal exercise the volume of inspired air may reach values upwards of 190 liters per minute whereas cardiac output may reach 30 liters per minute. Furthermore the ratio of alveolar surface area to pulmonary capillary blood volume is outstanding. It has been estimated that the total alveolar surface area allowing for gas exchange to take place in the lungs is roughly 50 square meters. This is roughly half the size of a tennis court. At any given time during maximal exercise the blood in the pulmonary capillaries is only 0.2 liters. Thus, 200 ml of blood is given a huge surface area for diffusion to take place. This results in almost 100% oxygen saturation of the blood that is leaving the pulmonary circulation and entering the left atria. The limitation to aerobic performance lies in the cardiovascular system’s ability to deliver this oxygen rich blood to the tissues. Because a healthy respiratory system does not limit performance, it undergoes little change in response to exercise training. Minor rather insignificant changes have been recorded in lung volumes, respiratory rate, and pulmonary diffusion.

**Metabolic Systems**

In many ways the movements of a human being can be compared to that of a machine such as an automobile. Like an automobile, the metabolic machinery of an exercising human transforms chemical energy (foodstuffs) into mechanical energy (movement). Like a machine, increasing the workload requires that more energy be used to fuel the activity. The beginning of this section examines the bioenergetics of the human. It explores various systems of the body used to convert chemical energy into mechanical energy. The lesson goes on to report the transient and permanent adaptations that take place in these systems due to exercise.
The beginning of this lesson will illustrate the various mechanisms cells of the body use to produce ATP. A quick review of these three systems is indicated. A fundamental understanding of them is necessary to comprehend further topics regarding this metabolic machinery. The discussion will continue to describe the transient changes that are orchestrated inside a cell at the onset of exercise. It will also discuss permanent cellular adaptations that result from exercise training. This lesson begins with the topic of ATP. Understanding it’s structure gives insight to it’s function.

**ADENOSINE TRIPHOSPHATE (ATP)**

At the cellular level our bodies are not directly able to utilize the chemical energy from the foodstuffs we ingest. For cells, the energy in the carbon-hydrogen bonds of foodstuffs (crude fuel) has to be converted to a usable compound known as adenosine Triphosphate (ATP) (refined fuel). ATP contains adenine (a nitrogen base), ribose (a five carbon sugar), and three phosphate groups (See figure 5).

ATP plays a pivotal role in cellular metabolism it acts as a “common chemical intermediate” that will function in both exergonic (energy releasing) and endergonic (energy absorbing) reactions.

From looking at the figure, one will notice that the energy in the ATP molecule (its ability to do work) lies in the three negatively charged phosphate bonds. Because of their negative charge, the phosphates are repelling from one another. An enzyme known as ATPase is able to split the terminal phosphate from the compound. When this terminal phosphate group is split or hydrolyzed, energy is released. Roughly 60%-70% of the total energy released is degraded to heat. The cell is able to harness the remaining energy and uses it to perform work.

Notice in this exergonic (energy releasing) reaction the terminal phosphate is split from ATP and results in adenosine diphosphate (ADP), an inorganic phosphate (Pi), and energy.

\[
\text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{Pi} + \text{Energy}
\]

**ENERGY SOURCES**

The production of new ATP in skeletal muscle as well as most cells is generated via three different mechanisms. These are in consecutive order from the most rapid to the slowest acting.

1. The creatine phosphate system
2. Glycolysis
3. Oxidative phosphorylation
THE CREATINE PHOSPHATE SYSTEM

The creatine phosphate system commonly called phosphocreatine (PCr) consists of an additional high energy phosphate molecule that the cells use to store energy. In fact, during rest, skeletal muscle cells store more energy in the form of PCr than ATP. A rested muscle cell contains roughly five times more PCr than ATP. Unlike ATP, however, PCr is not used directly by the cell to release energy. Instead PCr is used to replenish ATP supplies when they are diminished. The typical low levels of ATP in the cell are advantageous. They allow the cell to monitor and supply the demands of immediate metabolic needs. The rate of cellular metabolism mechanisms are dependent on the ratio of ATP, ADP, and Pi. At the onset of exercise, fluctuations in these levels occur. This will stimulate further metabolic machinery of the cell into action.

In a rapid reaction that requires no special structures of the cell, the enzyme creatine kinase (CK) facilitates the separation of PCr. In doing so, energy is liberated. The products left over are creatine (Cr) and inorganic phosphate (Pi). The energy released from this reaction is used to join Pi to an ADP molecule, quickly forming new ATP. Due to the quick speed of the reaction, creatine phosphate provides an immediate energy source to replenish supplies of ATP. This type of energy delivery system is essential for movements that require short explosive bursts of power that require only a few split seconds. The following is an example of how Creatine Phosphate (PCr) is used to generate more ATP.

In review, the creatine phosphate mechanism plays a vital role in muscle contraction. It is able to provide almost instantaneous replenishment of ATP. Without it, immediate muscle contraction would not be possible. Recall that ATP stores in a resting muscle cell are quite low. At the onset of exercise, the PCr system supplies contracting muscle cells with the first few vital seconds of ATP. This allows glycolysis (the second fastest acting energy system) to initiate before the stores of ATP are exhausted.

GLYCOLYSIS

Intense muscular contractions lasting beyond 15 seconds cannot be sustained without the contribution from another energy source. Although not as fast acting as the PCr system, Glycolysis serves as a relatively fast energy producing mechanism. Its advantage is the fact that it can operate in the absence of oxygen. For this reason it is considered “anaerobic”. It is stimulated within the first few seconds of exercise due to the fluctuation in ATP, ADP, and Pi. Glycolysis involves the breakdown (lysis) of glucose molecules. No special organelles of the cell are needed for glycolysis to occur. It is accomplished via glycolytic enzymes which are present in the cytosol of the cell. Glycolysis is much more complex than the
PCr system of replenishing ATP. It involves 12 steps which enzymatically break down glucose or glycogen to produce ATP.

Although quick acting, glycolysis is not an optimal producer of ATP. Relatively speaking, when compared to oxidative phosphorylation, it produces small amounts of ATP. Furthermore, the ATP produced by glycolysis comes at a metabolic price. A bi-product of glycolysis is pyruvic acid, which in the absence of oxygen is converted into lactic acid. Vigorous muscle contraction for a prolonged period of time results in rapid rates of glycolysis. Consequently, large amounts of lactic acid accumulate in the blood. Elevated lactic acid actually hinders the rate of glycolysis. This serves as a protective mechanism to prevent an acidic environment which can damage cells. More on this later.

While the process of glycolysis produces lactic acid and contributes relatively low levels of ATP, it does have some benefits. As stated earlier it can take place in the absence of oxygen. This is advantageous because an immediate and continuous oxygen supply to the muscle is not always possible. Furthermore, glycolysis needs no special organelles. It can take place anywhere in the cytosol of the cell. Lastly, glycolysis provides enough ATP to the muscle allowing it to contract until the third and final energy system is initiated.

**Oxidative Phosphorylation**

The third and type of ATP producing system is known as oxidative phosphorylation. Unlike the PCr and glycolytic systems, oxidative phosphorylation can only function under special conditions. It requires oxygen delivery to organelles known as mitochondria. The process by which fuel is broken down with the aid of oxygen is known as cellular respiration. It is considered an “aerobic” process due the presence of oxygen. In order for this mechanism to produce ATP, oxidative phosphorylation requires that both oxygen and a fuel source be present at the mitochondria. In muscle cells the mitochondria are conveniently located next to the contractile fibers which consume vast amounts of ATP while contracting. Utilizing a complex multi step process, the mitochondria is able to produce a relatively rich ATP supply compared to the other energy systems.

The mitochondria of the muscle cell is not completely dependent on a constant fuel delivery system. The muscle itself is able to store limited amounts of glucose in the form of glycogen. During moderate activities such as walking and light jogging, cellular respiration serves as the predominant ATP producing mechanism in the body. It’s an abundant ATP producer that provides the working muscle cells with sufficient energy, allowing moderate activity to continue for a prolonged period of time without fatigue.

As stated earlier, efficient operation of oxidative phosphorylation requires there be a constant supply of oxygen delivered to the mitochondria. This is accomplished via the blood stream. In addition, a bi-product of oxidative phosphorylation is carbon dioxide. The blood stream keeps the body from accumulating a build up of CO2 as it is able to absorb carbon dioxide where it is eventually given off by gas exchange in the lungs.
CHANGES IN ENERGY SYSTEMS INDUCED BY EXERCISE

THE PCR SYSTEM

Any movement of the musculoskeletal system involves muscular activity. At the onset of any movement, muscle cells begin contracting using ATP at a rapid rate. Although it is being broken down in mass quantities by the working muscle, the overall level of ATP is being maintained at relatively constant quantities. This is due directly to the degradation of PCR reserves. It would follow that during this time there is a rapid drop in the amount of PCR. See figure 6.

![Figure 6. Changes in ATP/PCr During Maximal Exercise](image)

The initial ATP and PCR stores within skeletal muscle cells are able to sustain maximal exercise for up to 15 seconds. During this short period of time other energy systems such as glycolysis are stimulated. They continue to supply contracting muscle cells with much needed ATP. Without an additional energy supply, the stores of both ATP and PCR would be diminished. This would lead to complete exhaustion of the muscle.

Very few studies have explored training effects on the PCR system. In a classic study, Costall et al. target the PCR system by having participants perform maximum effort leg extensions for six seconds. Although significant strength gains were found after training, the PCR system did not seem to be effected.8

CREATINE AS AN ERGOGENIC AID

In recent years, creatine supplementation has gained popularity with athletes in competitive sports which require short bursts of strength and speed. Studies have shown that athletes engaging in short-term high intensity activities are able to benefit their performance by supplementation of creatine.9,10,11 It has also found to increase phosphocreatine levels in people suffering from mitochondrial cytopathies.12 The logic behind creatine supplementation is to increase skeletal muscle creatine phosphate stores thus improving greater reynthesis rates of ATP. While numerous studies have illustrated the benefits of creatine supplementation for power type activities, it has been shown to have no effect on extended aerobic type exercises.10 Furthermore, creatine supplementation should be cautioned as long term effects are currently unknown.
GLYCOLYSIS

With high intensity exercises such as sprinting, the preferred fuel source is muscle glycogen. Muscle glycogen may be used at a rate thirty five times higher than it is used during moderate activities. Although supplies of blood glucose also provide the muscle cell with fuel, it has to first be transported to the cell and then into the cell. This process takes time. For this reason, muscle glycogen is used before blood glucose to fill the glucose needs of the cell. During prolonged activity however, as muscle glycogen runs out, the glucose needs are increasingly provided by the blood stream (see figure 7).

![Figure 7. Muscle Glycogen Depletion During Prolonged Exercise](image)

A repeating theme throughout this lesson will be skeletal muscle’s ability to adapt to the stresses forced upon it. Muscle glycogen stores are no exception. It would follow that a trained muscle contains a much greater capacity to store muscle glycogen than that of an untrained muscle. Muscle biopsies from trained long distance runners illustrated this fact. It was found that the runners had nearly twice the muscle glycogen levels as their sedentary counterparts. Increased glycogen stores are an obvious advantage. The more fuel storage a muscle contains, the longer it is able to sustain contraction before fatigue sets in.

As a result of training, further metabolic adaptations take place. It is well established that anaerobic training (high intensity bouts of exercise lasting 30 seconds or less) increases the glycolytic capacity of skeletal muscle. This is due directly to an increase in key enzymes which operate in the steps of glycolysis.

OXIDATIVE PHOSPHORYLATION

Perhaps the most dramatic transformations that take place to the energy systems are the changes involving cellular respiration. These improvements accompany aerobic training such as jogging and swimming. Although endurance training involves improvements to many different systems of the body, for now we will limit our focus on the changes that take place which have a direct result on oxidative phosphorylation. Recall that oxidative phosphorylation is highly depended on a constant supply of oxygen. This supply is provided by the bloodstream. Endurance training has been demonstrated to improve the rates of cellular respiration partially by the means of increasing blood supply to muscle cells. This is accomplished via the capillary system. The larger amount of capillaries allows greater gas, nutrient, waste, and heat exchange. Muscle biopsies of endurance trained athletes have shown to have as much as a fifteen percent higher capillary density than their sedentary counterparts. Furthermore studies have shown that improvements in capillary density and thus performance can take place in a relatively short
period of time. Significant increases in muscle capillary density have been shown to occur within as little as the first few weeks of training.¹³

Of course, greater oxygen supply due to increased capillary density does little good unless the muscle cell is able to deliver the oxygen to the mitochondria. Once oxygen has diffused out of the capillary, it is picked up and delivered by a molecule known as myoglobin. Myoglobin which has similar properties to hemoglobin serves as the oxygen delivery system from muscle capillaries to the mitochondria. Like hemoglobin, when combined with oxygen it has a deep red hue. Myoglobin gives muscle its distinctive red tint. It is not surprising that endurance training has been shown to increase the content of muscle myoglobin by as much as eighty percent⁷, thus improving oxygen delivery to the mitochondria. Furthermore, endurance type training has been shown to improve mitochondrial size and number. This obviously benefits the oxidative capacity of the muscle.

**NEUROMUSCULAR CONTROL OF MOVEMENT**

Each movement that a person makes takes planning, coordination, and execution by the nervous system. Most types of muscular movements are initiated at the motor cortex of the brain. These signals are then sent down the axons of neurons to the spinal cord. At the spinal cord these motor signals are passed to another neuron which travels to the muscle or effector. Skeletal muscle movements are executed by way of motor units. A motor unit is defined as a motor neuron and all of the skeletal muscle fibers (cells) that it innervates. Unlike smooth and cardiac muscle, a skeletal muscle fiber will not contract unless directly stimulated by a motor neuron. Thus, every individual skeletal muscle fiber contains a neuromuscular junction where a motor neuron is able to communicate with it (See Figure 8). This is advantageous, as it allows the motor division of the nervous system precise control over the number and degree of muscle fibers contracting. Simply put, the greater the number of fibers contracting the greater the force produced. Motor units can be small, innervating only a few fibers, or incredibly large innervating thousands of fibers.

Precise tasks such as movement of the eyes or manipulating a pencil require an incredible degree of accuracy. Motor units that contain only a few muscle fibers per neuron are utilized in situations such as these. When small motor units are excited, they cause contraction of relatively few muscle fibers. This allows for smaller movements which increase accuracy resulting in fine motor control. When the body requires a greater degree of movement such as sprinting, a greater number of motor units are engaged, thus there is a greater number of skeletal muscle fibers activated to contract. This phenomenon is known as motor unit recruitment. It is interesting to note that the smallest motor units (ones containing the fewest amounts of fibers) are always recruited first. This is due to the fact...
that the neurons of smaller motor units have a smaller cell body resulting in a lower threshold, thus they are excited and depolarize before the larger motor units.

For example, if a person attempted to curl a 30 lb. dumbbell they would start by recruiting motor units in lets say, the biceps brachii muscle. The smallest motor units would cause contraction of a few fibers. These few fibers contraction would not produce enough force to curl the dumbbell. Therefore, the person would recruit more and larger motor units until enough fibers contracted to overcome the 30 lb. weight.

Motor unit recruitment is just one small element of motor control. The ability of the body to orchestrate complex movements is only feasible if the brain is made aware of the body’s position is in space. How would you know where your arm is if you closed your eyes and waved it around? The answer is proprioception. The body has a number of receptors known as proprioceptors that monitor changes in joint position as well as muscle length and strain.

A muscle spindle fiber is a type of neuron that provides the brain and spinal cord with proprioceptive input. The dendritic or receptive end is integrated parallel with the muscle fiber. When the muscle fiber stretches the muscle spindle also stretches relaying information on the absolute length of the fiber as well as the rate in which it is being stretched. Muscle spindle fibers are very sensitive to the rate of elongation, in other words, a muscle extending rapidly causes them to send action potentials down their axons to signal and alert the brain or spinal cord. The spinal cord or brain then integrates this information, and initiates an appropriate response. Muscle spindle fibers are involved with numerous spinal reflexes. They are also affected dramatically by training and play a key role in allowing the musculoskeletal system to adapt to the stresses placed upon it.

Another type of proprioceptor that adapts to the stresses of exercise training is the Golgi tendon organ. The special receptive end of this neuron is situated near the muscle’s tendon. Unlike muscle spindle fibers which sense and relay information on muscle movement and length, Golgi tendon organs monitor the strain of a muscle. When a muscle is under severe strain to the point where injury could result, Golgi tendon organs signal the central nervous system which responds by inhibiting contraction of the muscle (agonist) causing the strain, thus decreasing the chance of injury. This is known as autogenic inhibition.

**NEUROMUSCULAR ADAPTATIONS TO RESISTANCE TRAINING**

There are drastic neuromuscular adaptations that result from chronic exercise such as resistance training. The types of adaptations that take place are specific to the type of exercise endured. This is known as training specificity. For example, a power lifter’s training regimen will include lifting extreme amounts of weight. The outcome of this type of training will result in strength gains of the muscle, it will not, however, result in the muscle increasing its aerobic or endurance capacity.

It is well established that a person, young or old, male or female, starting a proper resistance training (weight lifting) program is able to see incredible gains in a relatively short period of time. Within three to six months after starting a weight training program many can improve their strength by more than 100%. The strength gains accompanied by training are not the result of a single mechanism. Training triggers a number of neural as well as muscular adaptations that together produce vast improvements in strength.

For years it was assumed that strength gains accompanied by resistance training were due exclusively to increases in the muscle size (hypertrophy). This is a logical assumption because as the muscle fiber increases in size it gains more contractile proteins allowing for a more forceful contraction. The opposite is also true. An immobilized limb in a cast for example, will experience decreases in muscle size (atrophy). The atrophied muscle is paralleled by decreases in strength.
The problem with the former assumption is that strength gains due to training have been demonstrated to take place in the absence of muscle hypertrophy. For example, radical increases in strength have been recorded in people after only after a few weeks of starting a resistance training program with no accompanying evidence of hypertrophy. Furthermore, women who weight train experience relatively similar strength gains to that of men but experience much less hypertrophy of involved musculature. Surely, muscle hypertrophy is involved with strength gains, but there must be other contributing components. A number of neural adaptations take place that explain strength gains in the absence of hypertrophy (See Figure 9).

- Motor unit recruitment - In response to strength training the nervous system adapts by allowing the motor system to increase the efficiency and number of motor units activated. This increases the amount of fibers contracting and thus increase the force of contraction.

- Decreased autogenic inhibition - With resistance training, the strain gauges known as Golgi tendon organs become less sensitive to the tensile strain on the muscle. This decreases their response to inhibit the muscle contraction, thus a more forceful contraction can result.

Muscle hypertrophy explains the continuing strength gains seen weeks after the initiation of the resistance training program. Although it varies heavily from individual to individual, muscle hypertrophy is first seen roughly the tenth week after starting a resistance training program. Hypertrophy is basically due to an overall surplus of protein synthesis vs. degradation. With muscle hypertrophy the size of the muscle cell (fiber) becomes bigger. The increase in size is due to an increase in contractile proteins within the cell. The increased number of contractile proteins leads to increase in the overall force of contraction produced by the muscle.

Previously hyperplasia (increases in cell number) has been proposed to play a part in strength increases seen with resistance training. A number of studies have investigated this phenomenon and have concluded that there is very little if any hyperplasia in human skeletal muscle due to resistance training. It is not a significant contributing factor in strength gains.

**MUSCLE SORENESS**

Soreness in muscle can emerge at two different periods: during the activity and between 12 to 48 hours after the activity. Muscle soreness during the activity is known as acute muscle soreness. It is brought about by the build up of lactic acid produced by the working muscle. Acute muscle soreness presents a burning sensation during the activity that dissipates once the activity has stopped.
**DELAYED ONSET MUSCLE SORENESS (DOMS)**

Anybody that has ever started a resistance training program knows that the days following a hard workout can be filled with sore achy muscles. Structural damage to the muscle cell has been proposed as part of the reason for delayed onset muscle soreness. It is not surprising that high intensity bouts of training will produce damage to the muscle cell. This is evident in the enzymes that damaged muscle cells release into the blood. These enzymes have been demonstrated to increase up to 10 times their normal levels. However, in many instances, researchers have had subjects induce muscle damage through bouts of exercise in which the enzyme levels have risen with no incidence of muscle soreness that accompanies muscle damage. Therefore, structural damage only partially explains the phenomena of DOMS.

The inflammatory reaction can better explain muscle soreness. As stated earlier, there is a considerable amount of structural damage to muscle fibers after heavy bouts of exercise. In some instances the cell membrane completely ruptures allowing the cell contents to spill into the tissue. More frequently the cells are stretched to the point where some of the proteins providing structural support are torn. This cell damage initiates an inflammatory reaction which peaks 24-36 hours after the exercise bout, closely matching the incidence of muscle soreness. After a heavy bout of exercise, the cascade of events that lead to delayed onset muscle soreness have been sequenced as follows:

1. The muscle and connective tissue associated with the muscle incur damage.
2. Tissue damage initiates the inflammatory process (24-36 hours after exercise bout)
   - Increased blood flow and permeability in the area
     - Caused by increases in histamine, serotonin, prostaglandins
     - Increase of white blood cells in the area
     - Edema
   - Increased muscle temperature
3. The inflammatory phase is followed by a healing phase
   - Ongoing protein and collagen synthesis

There is also evidence that exercises involving eccentric contractions produce more muscle soreness than activities involving concentric contractions. Eccentric contractions are contractions of the muscle when it is lengthening. Concentric contractions take place when the muscle is contracting and getting shorter. For example, a person is going to recruit their biceps brachii muscle to curl a dumbbell. When they curl it up the biceps muscle is contracting and becoming shorter. This is known as concentric contraction. When they are letting the weight down and the muscle is getting longer it is known as eccentric contraction. Many studies have shown that resistance training involving eccentric (muscle lengthening) contractions produces a higher incidence of DOMS than concentric (muscle shortening) contractions. The reason behind this is evident. Eccentric activities simply produce more muscle damage and thus elicit a greater inflammatory response than concentric activities.

**NEURAL AND HORMONAL RESPONSES TO EXERCISE**

Because the nervous and endocrine system work closely together to maintain homeostasis, these two systems are sometimes known as the neuroendocrine system. As with many other systems of the body
the neuroendocrine system is affected by exercise. Both transient and prolonged adaptations occur with training.

**THE AUTONOMIC NERVOUS SYSTEM**

The autonomic nervous system (ANS) is affected in a predictable manner by exercise. Recall that the ANS is composed of the sympathetic (fight-or-flight) and the parasympathetic (rest-and-digest) divisions. Most visceral organs are innervated by the fibers of both systems. In general, the sympathetic and parasympathetic divisions exert opposite effects of one another. In most instances both systems are exerting some influence on the organs at the same time. It other words, on a particular organ there is an ongoing influence of sympathetic and parasympathetic tone. Under certain circumstances, the tonal activity of one division can exceed the other dominating the influence over the organ.

**THE AUTONOMIC NERVOUS SYSTEM RESPONSE TO EXERCISE**

Under stressful situations such as strenuous exercise, the sympathetic or fight-or-flight division of the ANS dominates its influence over the body. Its actions prep the body for fight or flight situations. The following table reviews the effects of the ANS on various organs:

<table>
<thead>
<tr>
<th>Organ</th>
<th>Effect of Sympathetic Stimulation</th>
<th>Effect of Parasympathetic Stimulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart</td>
<td>↑ HR ↑ contractility</td>
<td>↓ HR ↓ contractility</td>
</tr>
<tr>
<td>Blood Vessels</td>
<td>Constriction at most organs, dilation at heart, lungs and skeletal muscle</td>
<td>Dilation of minor vessels</td>
</tr>
<tr>
<td>Liver</td>
<td>Glycogenolysis (glucose released into blood)</td>
<td>None</td>
</tr>
<tr>
<td>Adipose Cells (fat stores)</td>
<td>Lipolysis (fatty acids released into blood)</td>
<td>None</td>
</tr>
<tr>
<td>Adrenal Medulla</td>
<td>Stimulation of epinephrine and norepinephrine secretion into blood</td>
<td>None</td>
</tr>
<tr>
<td>Pancreas</td>
<td>↑ glucagon secretion, ↓ insulin secretion</td>
<td>↓ glucagon secretion, ↑ insulin secretion</td>
</tr>
</tbody>
</table>
**HORMONAL RESPONSE TO EXERCISE**

Hormonal response to exercise is complex. The release of hormones is controlled by both neural and local factors. The release of these hormones is aimed at maintaining homeostasis disturbed by exercise.

**NOREPINEPHRINE AND EPINEPHRINE**

Because stressful situations elicit a sympathetic response, it is not surprising that during high intensity bouts of exercise, the sympathetic division of the ANS becomes predominant. One of its influences which trigger dramatic effects resides in the adrenal medulla. When stimulated the adrenal medulla releases a concoction of hormones known generally as adrenalin. Specifically the adrenal medulla secretes a mixture of 80% epinephrine and 20% norepinephrine. These catecholimines are released into the blood and elicit powerful effects that reinforce those of sympathetic stimulation. Unlike the sympathetic nervous system, however, these hormones do not have direct stimulation over the various organs of the body. They exert their effects by being released into the bloodstream where they travel and are picked by receptors of cells. The disadvantage of catecholamine response is it lags behind direct neural stimulation, but it is advantageous in the fact that these hormonal influences last for a prolonged period of time when compared to neural sympathetic influences. The following figure (figure 10) represents the changes in norepinephrine and epinephrine levels as the intensity of exercise increases. Notice that the stress of exercise will elicit a surge in these catecholimines at different intensities. Upon the termination of exercise, the adrenal medulla is no longer stimulated to release its catecholamine concoction. The circulating levels of norepinephrine and epinephrine are taken up by cells and the levels drop. Notice epinephrine returns to resting levels within a few minutes after the exercise has stopped, while norepinephrine levels may stay elevated for hours after the exercise bout.

**HORMONAL EFFECTS ON FLUID BALANCE: ADH AND ALDOSTERONE**

As stated previously, exercise induces a shift of fluid from plasma to tissues resulting in decreased blood volume and blood pressure. This decrease may impede cardiovascular and thermoregulatory homeostasis. The kidneys are utilized to counterbalance the drop in blood volume with the influence of two hormones.

When blood volume drops due to exercise the plasma becomes more concentrated. This triggers chemoreceptors in the hypothalamus to release antidiuretic hormone (ADH). ADH targets the collecting ducts of the kidneys to retain more water thus minimizing the loss of fluid through urine production. Similarly, aldosterone released by the adrenal cortex causes the kidneys to retain more water by signaling
the kidney to retain more sodium (water follows sodium). The net effect of these two hormones is increased water retention which increases plasma volume helping to restore blood pressure to normal.

**HORMONAL INFLUENCE ON BLOOD GLUCOSE REGULATION**

The ability to keep blood glucose concentration at healthy levels is of major importance to the body. In order to function properly the central nervous system requires a constant delivery of glucose to its cells. The brain depends on it as a fuel source. Within plasma, blood glucose concentrations are typically held in between 70-110 mg/100 ml. Even small fluctuations in this value can be dangerous. Decreases in blood glucose levels beneath 70 mg/100 ml are an immediate cause for concern as hypoglycemia may cause mental confusion, coma, and death. Although less critical, chronic hyperglycemia (blood glucose levels >110 mg/100 ml), as in diabetes mellitus, reeks havoc on the body as it may cause a plethora of chronic conditions such as diabetic neuropathy and artherosclerosis.

The two hormones that are the most influential in regulating cellular fuel metabolism and blood glucose levels are insulin and glucagon. Depending on whether the body is in a state of feasting or fasting, these two hormones allow the body’s cells to switch from a state of anabolism to catabolism respectively. They are also directly involved in the maintenance of blood glucose homeostasis. Due to the importance of these hormones a quick review is indicated.

Regulation of insulin or glucagon secretion is due primarily to concentrations of plasma glucose. In a healthy individual, after a meal, plasma concentrations of glucose rise as the food is absorbed through the gut into the bloodstream. As glucose concentrations approach 110-130 mg/100 ml, pancreatic β (beta) cells are stimulated to release insulin. Insulin acts to (1) inhibit glucagon and (2) stimulate cellular uptake of plasma glucose. Therefore, a rise in insulin secretion causes a decrease in blood glucose concentration.

During fasting or exercising, the blood glucose concentration falls. As it approaches 60-70 mg/100 ml pancreatic α (alpha) cells are stimulated to release glucagon. The effects of glucagon are antagonistic to that of insulin. Glucagon prevents cellular uptake of glucose into organs such as muscle and adipose tissue, while triggering the liver to release glucose into the bloodstream. As a result of glucagon secretion, plasma concentrations of glucose rise, bringing the system back into homeostasis. Thus, the maintenance of blood glucose concentration is provided by a negative feedback system of these two hormones. In a normal healthy individual this precise system controls fluctuations in blood glucose in a consistent manner. Deviations such as increased blood glucose from a meal are quickly brought back within normal homeostatic levels. (See Figure 11)
In diabetes mellitus, however, there is a flaw in this mechanism. With type I diabetes sufficient insulin amount is lacking due to damage to the pancreatic beta cells. With type II, insulin sensitive tissue (especially muscle and adipose) has become resistant, thus not as responsive to the presence of insulin. Even though there is no shortage of insulin, the cells of these tissues do not respond to it adequately. The problem is further exacerbated by the fact that the beta cells will continue to increase their insulin production in response to elevated glucose levels. This action only makes the cells more resistant to the hormone, decreasing the ability to effectively lower elevated blood glucose levels. Figure 12 is a diagram depicting the response of a healthy individual and a diabetic to a glucose tolerance test in which the subjects drank a solution containing 100 grams of glucose. From the figure you will notice that the diabetic's blood glucose level is not being maintained within normal homeostatic limits.

**REGULATION OF BLOOD GLUCOSE DURING EXERCISE**

As noted earlier, when insulin is released during resting conditions it causes most cells of the body to uptake glucose thus lowering blood glucose levels. In most cells, this action is accomplished by glucose transporters. There are many different types of glucose transporters, but they all work by eliciting facilitated diffusion of glucose across the plasma membrane. GLUT 4 is a glucose transporter that is abundant in tissues such as muscle and adipose which account for the majority of glucose uptake from blood.

In resting skeletal muscle GLUT 4 is activated by only by insulin. Once activated the intracellular pool of these protein transporters fuse with the plasma membrane of the cell allowing glucose to diffuse in. The presence of insulin at these cells results in an increase glucose uptake 10-30 times that of normal values.

Exercise has been shown to activate GLUT 4 transporters in skeletal muscle independent of insulin presence. This fact has significant implications for the diabetic. According to ACSM's Exercise Management for Persons with Chronic Diseases and Disabilities, regular physical activity has been shown to benefit both types of diabetes. They consider exercise as the “cornerstone” of diabetic care. ACSM's list of the effects of exercise training with diabetics include:
1. Improvement in blood glucose control
   - In type II diabetics, exercise along with diet and medication should be used as a means of controlling blood glucose levels.
   - Exercise is not considered a factor in blood glucose control of type I diabetics, although they are encouraged to exercise to gain overall benefits given the fact that their blood glucose is under relative control (<250 mg/100 ml).

2. Improved insulin sensitivity
   - Exercise results in increased sensitivity to the presence of insulin which may lead to a decrease in medication used to treat the disease.

3. Loss of body fat
   - In type II diabetics weight loss has been shown to increase insulin sensitivity thus leading to a decrease in medication used to treat the disease.

4. Cardiovascular Benefits
   - Exercise has been shown to improve cardiovascular parameters and decrease the risk of cardiovascular events. This is of particular importance to diabetics who are at greater risk for chronic cardiovascular complications.

5. Stress Reduction
   - Stress can have a negative impact on blood glucose levels at it can activate the sympathetic division of the nervous system which facilitates increases in blood glucose levels.

6. Prevention of type II diabetes
   - Numerous epidemiological studies have demonstrated that regular physical activity plays an important role in the prevention of type II diabetes.

**SPECIAL EXERCISE CONSIDERATIONS FOR PEOPLE WITH DIABETES**

Prescription of exercise in the diabetic should be catered to the individuals particular circumstances. Consideration of complications, goals, and benefits should be addressed. The ACSM lists precautions as follows:

- Before exercise in the diabetic blood glucose level should be administered.
- A source of rapidly acting carbohydrate should be kept readily available at all times.
- The diabetic should ingest adequate fluid before, during, and after the exercise bout.
- Proper footwear should be worn.
- The patient should always carry medical I.D.
- Exercise that produces excessive heights in blood pressure should be avoided due to possible microvascular complications.
Contraindications to exercise are listed as:

- Any retinal hemorrhage or recent therapy for retinopathy.
- Illness or infection is present.
- Blood glucose levels exceed 250mg/100ml
- Blood glucose levels are less than 100mg/100ml
  - Should this be the case, carbohydrates should be ingested and blood glucose should be allowed to rise before initiation of exercise bout.

**Exercise Prescription**

It should be stressed to the individual that the most important aspect of any exercise prescription is adherence to the program. In 1978 ACSM published its first position statement on physical activity and health. In it they declared that to gain health benefits, a person should participate in aerobic activity such as walking 3-5 days a week at an intensity of 60-90% of maximum heart rate. At this high intensity, cardiorespiratory fitness is addressed, but one can imagine the attrition rate of engaging in physical activity day after day that was painful, especially for the unconditioned person starting an exercise program.

A more recent statement from the U.S. Department of Health and Human Services claims that individuals who are in poor physical fitness, obese or middle aged to elderly can benefit fitness and improve disease factors simply by engaging in low intensity bouts of exercise roughly 50% of heart rate max. Based on this knowledge, ACSM has indicated that any unfit or previously sedentary individual starting an exercise program should be conservative and start out at an intensity of roughly 40% of heart rate max.

An individualized approach must be used with exercise prescription. The healthcare professional should be aware of the person’s medical, health and fitness status as well as the individual’s goals before setting forth an exercise protocol. The following section will focus on providing a general exercise prescription focused on increasing the overall wellbeing of relatively healthy individuals.

**Warm-up**

It should be noted that the exercise bout should always be preceded by a warm-up session. A warm-up is designed to ready the body for activity. It should slowly bring the person up in intensity until that person is exercising at their target heart rate. The benefits of a warm-up include:

- Increased blood flow to working musculature
- Increased speed and efficiency of nerve impulses to working musculature
- Decreases incidence of injury to connective tissues such as tendons and ligaments
- Induces sweating which aids in thermoregulation
- Activation of the various metabolic energy systems
- Decrease in muscle viscosity leading to increased muscle efficiency and power
- Preparing the cardiorespiratory system to increasing workloads
ACSM recommends physical activity most days of the week. It has been demonstrated that health related benefits are linked to physical activity in a dose-response manner. Increasing the frequency of exercise sessions to most days of the week maximizes the health benefits.

**INTENSITY**

As stated previously, one should be conservative on intensity levels of exercise when first embarking on an exercise program. The initial conditioning phase of an unfit individual should start at 40% of heart rate Max. For example a 40 year old unfit man would exercise at a target heart rate of 40% of his age predicted heart rate maximum.

\[
220 - \text{age} = 180 \quad \text{(age predicted max heart rate)}
\]

\[
180 \times 0.4\% = 72 \text{ beats per minute.}
\]

In many instances with unfit individuals, the target heart rate in the initial conditioning phase may be at or below the person’s resting heart rate. In this situation the healthcare professional should use a rating of perceived exertion (RPE) scale, increasing the intensity of exercise until the subject reaches a 4 out of 10.

As described in previous sections of this course, physiological changes take place quickly in response to exercise, especially in the unfit populations. Recall that adaptations to aerobic exercise may take place in as little as two weeks or less. Therefore, the initial conditioning phase should be short lived and increased as improvements in the individual are observed. It is recommended that the patients intensity be increased anywhere from 50-85% of heart rate maximum depending on progress and fitness level.
**TYPE**

In the initial conditioning phase, the type of exercise should be aerobic. In the absence of any orthopedic problems, walking is the recommended aerobic exercise for individuals as it is effective, familiar, and readily available.

**TIME**

The duration of the exercise depends on the fitness parameters of the individual. Beginners are recommended to engage in 10-20 minutes of continuous activity, whereas it is recommended that more fit individuals exercise continually for up to 60 minutes. ACSM recommends that individuals beyond the initial conditioning phase get at least 30 minutes of exercise per session. It has also been found that individuals may gain health benefits by splitting up the 30 minutes of exercise into three ten minute sessions. This is especially helpful to people with daily time constraints.

**WARM-DOWN**

The warm-down is designed to lower heart rate and body temperature which were both elevated from the exercise session. Slowly decreasing exercise intensity for 5-10 minutes following the exercise bout increases recovery more rapidly than if a subject was to stop completely after the exercise bout. The following figure (figure 13) is a visual representation of a typical exercise session for a healthy young adult. Notice that a steady-state heart rate is maintained for at least 30 minutes.

![Figure 13. Typical Aerobic Exercise Session of Healthy Young Adult](image)

**MUSCULOSKELETAL CONDITIONING**

To complete the package of a well balanced exercise regimen, muscular strength and endurance exercises (strength/resistance training) should be performed. Resistance training can be performed following the warm-down period of an aerobic session, or it can substitute an aerobic workout on alternate days. ACSM recommends that an individual participate in strength training 2-3 days per week. During the session the individual should engage in a minimum of one set of 8-12 repetitions for 8-10 different exercise that work major muscle groups. It is recommended that any individual beginning a strength training should be instructed by a certified professional. There are many features of an appropriate strength training regimen, and if done improperly, injury could result.
CONTRAINDICATIONS TO EXERCISE

There are some individuals in which the risks of exercise outweigh the benefits. For these individuals ACSM has established absolute and relative indications to terminate exercise or exercise testing. Absolute indications require the exercise to be terminated regardless of circumstances, relative indications are guidelines in which the clinician uses to evaluate the risk/benefit ratio.

### Absolute Indications for the Termination of Exercise

1. Drop in systolic blood pressure of greater than or equal to 10 mmHg from baseline BP despite and increase in workload, when accompanied by other evidence of ischemia
2. Moderate to severe angina
   - Greater than or equal to 2 on a 1-4 scale
   - Increasing nervous system symptoms
   - Ataxia, dizziness, or syncope
3. Signs of poor perfusion
   - Cyanosis or pallor
4. Technical difficulties monitoring the patient
   - ECG or BP
5. Subject’s desire to stop
6. Sustained ventricular tachycardia
7. ST elevation greater than or equal to 1 in leads without diagnostic Q-waves

### Relative Indications for the Termination of Exercise

1. Drop in systolic blood pressure of greater than or equal to 10 mmHg from baseline BP despite and increase in workload, in the absence of other evidence of ischemia
2. ST or QRS changes
3. Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
4. Fatigue, shortness of breath, wheezing, leg cramps, or claudication
5. Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
6. Increasing chest pain
7. Hypertensive response
   - SBP > 260 mmHg
   - DBP > 115 mmHg
Conclusion

Over the years our society has become more and more sedentary. Inactivity has been linked to a wide array of chronic and morbid conditions. In 1992 the American Heart Association (AHA) added physical inactivity to their list of major risk factors for heart disease including smoking, high blood pressure, and high cholesterol. In 1996, the American Cancer Society linked a sedentary lifestyle to certain forms of cancer. Furthermore, countless studies have linked physical inactivity to chronic conditions ranging from obesity to depression.

It is no doubt that the majority of the American population would incur vast health benefits from participating in an exercise regimen. Done properly and regularly, exercise has proven to be effective in improving the wellness of individuals who choose to make it part of their lifestyle. Over the decades mounting evidence reports that regular exercise is an essential ingredient for improving the overall quality of life. Unlike other lifestyle choices, regular exercise is unsurpassed in its ability to prevent such a wide variety of chronic conditions ranging from diabetes to immobility.

It is no doubt that exercise not only adds years to one’s life but life to one’s years. The extensive improvement of quality of life is clearly illustrated when examining the impact of exercise on different systems of the body. The metabolic, musculoskeletal, nervous, endocrine, and cardiovascular systems all show improved functioning in response to regular exercise. Furthermore, exercise need not be vigorous or painful to promote these changes. In fact, the most radical changes take place in the systems of unfit or previously sedentary individuals who become moderately active.

Any health care professional involved with patient education should encourage proper exercise to promote a healthier lifestyle. To do so, the health care professional should have a basic understanding of the transient and permanent physiological changes that take place in the body as the result of exercise. Furthermore, the educator should be aware of the contraindications to exercise where the risks outweigh possible benefits. Lastly, the ability to utilize these basic concepts and apply them to prescribe a safe and appropriate exercise regimen is essential to the goal of preventative medicine.
REFERENCES


CE EXAM
THE BASICS OF EXERCISE PHYSIOLOGY

1. Max heart rate estimate is:
   a. 200 for all populations and ages
   b. 220 minus age
   c. Based on the pumping capacity of the heart
   d. Determined by an individual’s stroke volume

2. Stroke volume:
   a. Rises in a linear fashion related to workload
   b. Represents the amount of blood pumped out of the heart each minute
   c. Increases as the amount of blood returning to the heart increases
   d. Continues to increase with increasing workloads until 40-60% of maximal workload

3. During exercise in a healthy individual:
   a. Systolic BP increases while diastolic BP remains relatively constant
   b. Systolic and diastolic BP increase
   c. Systolic BP remains relatively constant while diastolic BP increases
   d. Systolic BP decreases while diastolic BP increases

4. Resistance type exercise (weight lifting) elicits a greater response in blood pressure than endurance type activities:
   a. True
   b. False

5. Endurance type training does not increase:
   a. The plasma concentration of blood
   b. The osmotic gradient of blood
   c. The red blood cell volume
   d. The hematocrit value

6. An accumulation of carbon dioxide in the blood will not cause:
   a. An increase in the acidity of blood
   b. A decrease in the acidity of blood
   c. An increase in the rate of respiration
   d. An increase in the depth of respiration
7. Exercise training elicits major changes in:
   a. Lung volume
   b. Respiratory rate
   c. Pulmonary diffusion
   d. All of the above
   e. None of the above

8. The energy systems in order from slowest to fastest acting are:
   a. Creatine phosphate, glycolysis, oxidative phosphorylation
   b. Glycolysis, oxidative phosphorylation, creatine phosphate
   c. Oxidative phosphorylation, creatine phosphate, glycolysis
   d. Oxidative phosphorylation, glycolysis, creatine phosphate

9. In a well rested skeletal muscle cell:
   a. There are high levels of ATP stored
   b. There are low levels of ATP stored
   c. There are low levels of PCr stored
   d. There are high levels of ADP stored

10. The following is not a byproduct of glycolysis:
    a. Carbon dioxide
    b. ATP
    c. Heat
    d. Pyruvic acid

11. The energy system the produces the highest ATP yields is:
    a. Glycolysis
    b. Oxidative phosphorylation
    c. Creatine phosphate
    d. All produce similar amounts of ATP

12. Within the first few seconds after the initiation of exercise:
    a. ATP levels drop significantly
    b. ATP levels stay relatively constant
    c. PCr levels rise significantly
    d. PCr levels stay relatively constant

13. Creatine supplementation has been demonstrated to increase performance in endurance type activities:
    a. True
    b. False
14. Training which consists of high intensity bouts of exercise lasting 30 seconds or less has the greatest impact on:

   a. Muscle mitochondrial density
   b. Muscle myoglobin content
   c. Glycolytic capacity of the muscle
   d. Capillary density surrounding the muscle cells

15. Significant increases in muscle capillary density have been shown to occur within as little as the first few weeks of training.

   a. True
   b. False

16. Which is not a component of strength gains within the first few weeks of a resistance training program?

   a. Increased motor unit recruitment
   b. Autogenic inhibition
   c. Decreased sensitivity of Golgi tendon organs
   d. Muscle hypertrophy
   e. All of the above explain strength gains within the first few weeks of a resistance training program

17. Delayed onset muscle soreness (DOMS) is caused directly by structural damage of the muscle.

   a. True
   b. False

18. If one wants to incur major muscle damage he/she should utilize primarily ___________ contractions in their training program.

   a. Concentric
   b. Eccentric
   c. Isometric
   d. Isokinetic

19. Which is not an effect of parasympathetic stimulation on the body?

   a. Decreased heart rate
   b. Decreased contractility of the heart
   c. Decreased glucagon secretion
   d. Decreased insulin secretion

20. Which of the following statements is not true?

   a. The adrenal medulla secretes a mixture of 80% epinephrine and 20% norepinephrine
   b. Epinephrine is not released during exercise until roughly 50% of maximum exercise intensity
   c. The stress of exercise will elicit a surge in these catecholamines at different intensities
   d. The effects of these catecholamines lags behind those of direct neural stimulation
21. Exercise induces a shift of fluid from plasma to tissues resulting in decreased blood volume and blood pressure.
   
   a. True  
   b. False  

22. Antidiuretic hormone (ADH) release signals the kidneys to retain more water by causing them to retain more sodium.
   
   a. True  
   b. False  

23. Glut 4 transporters are abundant in _____________ tissue.
   
   a. Skeletal muscle  
   b. Adipose  
   c. Nerve  
   d. Both a and b  

24. In skeletal muscle Glut 4 transporters are activated by both exercise and the hormone glucagon.
   
   a. True  
   b. False  

25. Which is not a special exercise consideration for people with diabetes?
   
   a. Before exercise in the diabetic blood glucose level should be administered  
   b. The diabetic should ingest adequate fluid before, during, and after the exercise bout  
   c. Proper footwear should be worn  
   d. Exercise that produces excessive heights in blood pressure are recommended  

26. Which of the following is not a contraindication for exercise and diabetics?
   
   a. Any retinal hemorrhage or recent therapy for retinopathy  
   b. Illness or infection is present  
   c. Blood glucose levels exceed 200mg/100ml  
   d. Blood glucose levels are less than 100mg/100ml  

27. A 30 minute aerobic exercise section may be broken up into 3 10 minute sessions.
   
   a. True  
   b. False  

28. The four components of an aerobic exercise prescription are Frequency, Intensity, Type, and Time.
   
   a. True  
   b. False
29. Patients with established risks for a coronary event should have their blood pressure and heart rate administered prior to and during the exercise bout (every 2 to 3 minutes).

   a. True
   b. False

30. A hypertensive response during exercise is considered a SBP > 260 mmHg and or a DBP > 115 mmHg.

   a. True
   b. False
Your opinion is important to us. Please answer the following questions by circling the response that best represents your experience.

<table>
<thead>
<tr>
<th>COURSE OBJECTIVES &amp; CONTENT</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The activity was valuable in helping me achieve the stated learning objectives.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. The content was up to date.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2. The number of credit hours was appropriate for the content.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>TEACHING/LEARNING METHODS</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. The teaching/learning methods, strategies, and slides were effective in helping me learn.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. The material was clearly explained.</td>
<td>5</td>
<td>4</td>
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<tr>
<td>6. The answers to the post-test questions were appropriately covered in the activity.</td>
<td>5</td>
<td>4</td>
<td>3</td>
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<table>
<thead>
<tr>
<th>OVERALL ACTIVITY</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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<tr>
<td>7. The online course/download supported the achievement of the stated learning objectives.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>8. The material was relevant to my professional development.</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<tr>
<td>9. Overall, I am pleased with this activity and would recommend it to others.</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>10. The content was presented free of commercial bias. *</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>11. Did the material presented increase your knowledge and/or understanding of this topic? *</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td>NA</td>
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</tbody>
</table>
* If you responded “No” to question 10, please explain why:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

* If you answered “Yes” to question 11, what change do you intend to make?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

What barrier, if any, may prevent you from implementing what you learned?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Cite one new piece of information you learned from this activity:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

Additional comments/suggestions:

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________

With my signature I confirm that I am the person who completed this independent educational activity by reading the material and completing this self evaluation.

Signature ___________________________________________ Date:____________________
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UNDERSTANDING IMPLICIT BIAS

The goal of healthcare is to provide the best possible care to all patients; indeed, many healthcare professionals must recite a pledge similar to the Hippocratic oath upon licensure. However, it is possible for healthcare professionals to have implicit bias that leads to substandard care.

Implicit bias is an unconscious attitude leading to stereotypes that influence thought and action. Not being aware of this bias can lead to unintentional discrimination in patient assessment and diagnosis, treatment, follow-up care, etc. Discrimination, unconscious or otherwise, in these impacted areas of healthcare leads to disparities where disadvantaged patient populations receive unequal care. Patient groups especially at risk of receiving unequal care may include:

- Those with lower income
- Women
- Minorities
- Those who speak English as a second language
- The elderly

An example of healthcare disparities can be seen in breast cancer mortality rates. Black women are 41% more likely to die from breast cancer than white women. Additionally, they are less likely to be diagnosed with stage I breast cancer, but twice as like to die from early breast cancer.

Eliminating implicit bias can help reducing disparities in healthcare. Strategies for healthcare professionals to remove bias from their practice may include:

- Regulating emotions – being aware of, and control, thoughts and feelings
- Building partnerships – working with patients to achieve a common goal
- Taking perspective – understand the patient perspective during all phases of healthcare

Recognizing implicit bias and working to remove it from practice will help healthcare professionals to give the best care possible to all patients and reduce the disparities between patient populations.

REFERENCES


Aujero, M. Breast cancer screening for at risk women. Oral presentation at: 23rd Annual Breast Cancer Update; February, 2021; Wilmington, DE.

## WRITTEN PROGRAM REGISTRATION FORM

Date: _____________________________

Name & Title: ______________________________________________________________________

Address: _________________________________________________________________________

City: _____________________________ State: ___________ Zip: ________________

License No. (Required for Florida): _______________________________________________________________________

Email: _________________________________________________________________________

Employer: _______________________________________________________________________

(W): _____________________________ (H): _____________________________ (F): ____________

Have you registered with us before? ________ Yes  ________ No

<table>
<thead>
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<th>Course #:</th>
<th>Title:</th>
<th>Amount:</th>
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<td>CX0038</td>
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Paying By: _______Check  _______Credit Card  _______Money Order  _______Cash

Credit Card Number: ___________________________ Exp. Date: ______________

Cardholders Name: ___________________________ Sec. Code: ____________________

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