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INTRODUCTION

PREFACE

This course introduces the principles of exercise and sports physiology for trainers, doctors, and other practitioners interested in how the human body exercises and what happens during exercise. True exercise requires coordination of the brain, respiratory system, cardiovascular system, and muscles—each contributing to the act of exercising and the process of sports participation. We will talk about the components of the body necessary for exercise as well as the established ways that athletes can maximize their exercise performance. Also discussed are the interactions between disease states, disabilities, and exercise and the ways to manage injuries and illnesses related to training.

Chapter one introduces the topic of skeletal muscle anatomy and physiology, both at rest and with exercise. Essentially no exercise can happen without the coordination of skeletal muscle, which receives input from the nervous system in order to function. Muscle tissue is unique among other tissues of the body in that it stores energy at rest and utilizes that energy at a rapid rate, especially during intense exercise. How muscles function and adapt to exercise is also covered in this chapter.

Chapter two discusses the anatomy and physiology of the heart and how the cardiovascular system responds to exercise. Similar to the statement that no exercise can happen without muscle function, the heart and the blood vessels supplying muscle tissue are also crucial to the participation by an athlete in any sporting activity. Most exercise—in particular aerobic activities—involves the proper response of the heart and blood vessels to the act of exercising the human body. There is a great deal of stress placed upon the heart during any physical activity, making it a vital organ of study for the exercise physiologist.

Chapter three focuses on the respiratory system, what it involves, how it works, and how it responds to activity. The anatomy of the lungs is covered, including how they take in oxygen and exchange oxygen and carbon dioxide at the level of the alveoli. In addition, the chapter covers the way the two gases are transported in the body and how the reverse exchange happens at the tissue level. The way in which exercise influences the respiratory system is also covered.

Chapter four builds on the information learned about muscles in chapter one and discusses the role of anaerobic exercise, which is exercise that does not require oxygen. One of the main types of anaerobic exercise is resistance training which includes a wide range of activities designed to tone or build muscles. Resistance training or "strength training" is not just for bodybuilders and has a role in every person's exercise program. Types of resistance training and the way the body adapts to resistance training are discussed.

Chapter five is about the basics of aerobic exercise, the types of exercise involved in aerobic exercise, and the benefits of cross-training for an athlete. The term "aerobic exercise" translates to "exercise with air," implying that this is a type of activity that makes use of oxygen. Indeed, aerobic metabolism fuels aerobic exercise. There are many benefits to aerobic activities that differ from those seen in anaerobic exercise. Cross-training involves switching up activities in order to maximize performance, reduce injuries, and lessen boredom; this will be covered as part of this chapter.

Chapter six talks about exercise in extremes of temperature and altitude. Many athletes cannot exercise in temperate weather all the time and need to adjust their workouts to make accommodations for extreme cold or extreme hot weather. There are specific bodily responses to exercising in these extremes that need to be taken into account when working out. The chapter also talks about hot yoga, in which individuals practice yoga under conditions of high heat and humidity. High altitude exercise has received a great deal of attention among elite athletes, who train at high altitude to help them perform better at low altitudes; this is another component of this chapter.

The focus of **Chapter seven** is exercise training or sports training. One of the goals of the sports physiologist is to determine the best exercise prescription for the athlete starting or changing their exercise program. When aiding a person in starting an exercise program, there are certain questions that must be asked prior to starting the program and specific ways to start these types of programs. Before, during, and after training, it is a good idea to determine the athlete's body mass index (BMI) and body composition in order to follow their progress. In addition, some will want to use various ergogenic aids in order to maximize their performance, so this is discussed in this chapter.

Chapter eight covers the basics of the nutrition of carbohydrates, protein, and dietary fats. There is much misinformation about different types of foods and the role they play in athletics. There are many fad diets out there and many athletes have specific ideas about what foods they should eat or not eat before, during, and after training. This chapter offers solid information about the different types of macronutrients in the diet and how they are used as fuel sources for different types of training.

Chapter nine focuses on age and gender considerations in training and exercise. Children often start athletics at an early age and have developmental considerations involved in their training and exercise programs. Exercise clearly benefits children of all ages but their exercise programming must be weighed against their developmental issues. When it comes to exercise, much of the emphasis is on the male athlete so this chapter deals with the female athlete and her unique issues and concerns. The problems, challenges, and advantages related to being athletic as an older adult are also part of this chapter.

Chapter ten talks about exercise as it applies to individuals with cardiovascular or heart disease, those who have COPD (chronic obstructive pulmonary disease), patients with emphysema, and athletes or prospective athletes with asthma. People with these disorders have special challenges related to exercise and need to make adjustments to their exercise program in order to be able to be active. This isn't to say that these individuals cannot exercise; on the contrary, they can exercise and can have advantages to exercise that may enhance their physical fitness levels and levels of functioning in daily activities.

The topic of **Chapter eleven** is obesity and exercise. The obese person should be able to exercise despite being overweight and may have, as an effect of their exercise, the ability to lose some weight. In fact, few people can have weight loss and the ability to sustain their weight loss without some form of physical activity. The types of physical activity that can safely be undertaken in the obese patient and how much exercise should be done to lose weight are discussed.

Chapter twelve discusses type 1 and type 2 diabetes and the role that exercise has in the prevention and management of these disorders. Exercise is known to improve insulin sensitivity and to decrease the risk of developing type 2 diabetes. As you will see in this chapter, exercise is strongly beneficial in helping patients who already have type 2 diabetes. Individuals with type 1 diabetes will also benefit from exercise but should take special precautions with regard to diet and insulin use while being physically active.

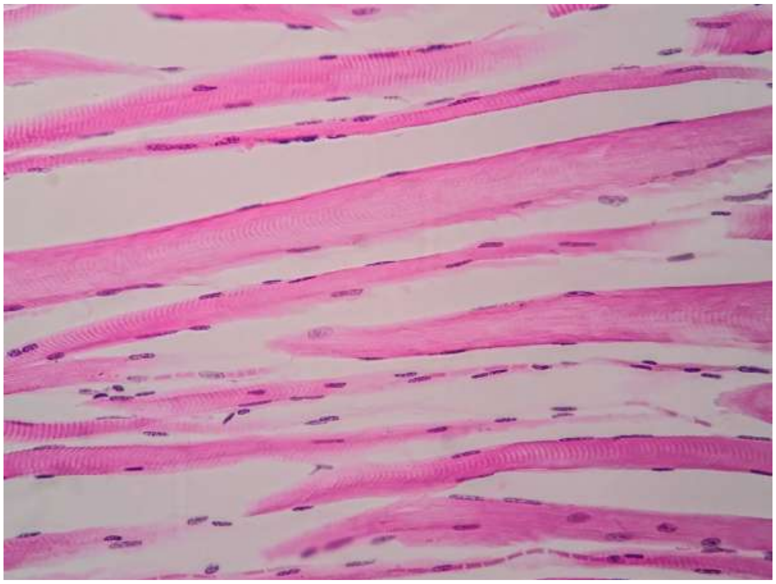
Chapter thirteen focuses on sports, exercise, and the various injuries the athlete can get while playing sports. It starts with the topic of overtraining in athletes as well as the relatively common “overtraining syndrome” in which the exercising athlete simply exercises too much and burns out when it comes to athletic performance. Muscle injuries in the athlete and other orthopedic injuries, including stress fractures of the lower extremities, are covered. There are many different orthopedic injuries an athlete can get, which are discussed as part of this chapter.

CHAPTER 1: MUSCLES AND EXERCISE

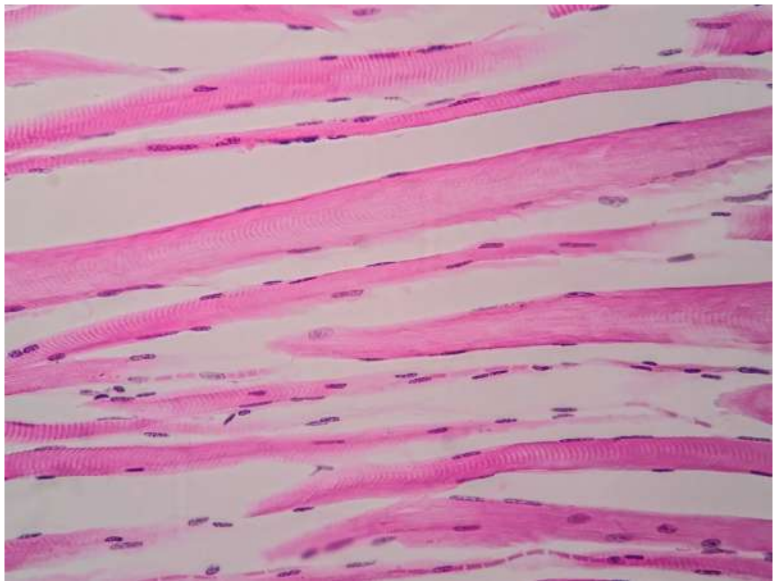
This chapter introduces the topic of skeletal muscle anatomy and physiology, both at rest and with exercise. Essentially no exercise can happen without the coordination of skeletal muscle, which receives input from the nervous system in order to function. Muscle tissue is unique among other tissues of the body in that it stores energy at rest and utilizes that energy at a rapid rate, especially during intense exercise. How muscles function and adapt to exercise is also covered in this chapter.

MUSCLE ANATOMY

While there are three types of muscle tissue, skeletal muscle, cardiac muscle, and smooth muscle, this chapter focuses primarily on skeletal muscle, which is also referred to as “voluntary muscle.” This type of muscle, like all muscle, has an inherent excitability because the cell membranes can go from being polarized to depolarized, with the ability to send an electrical signal from one end of the cell to another. This depolarization depends on specific signaling from the nervous system in order to receive the electrical signal. Figure 1 shows the regular nature of skeletal muscle cells:



Each skeletal muscle consists of several different integrated tissues. There are three layers of connective tissue, which are called “mysia” that enclose the muscle structures. The epimysium is the dense connective tissue surrounding each muscle, allowing it to contract and move as a unit and allowing the muscle to maintain its structure as it contracts. Figure 2 shows the muscle structure:



Inside each skeletal muscle, there are muscle fibers that are organized into bundles called fascicles—each of which is covered by a middle layer of connective tissue called the perimysium. Within the fascicle, there is a connective tissue layer around each muscle fiber, called the endomysium. There are nutrients and fluids carried by the endomysium that will supply the needs of the individual muscle fiber. Remember that each muscle fiber is itself a single cell.

The mysia will intertwine with the collagen of a tendon in order for the muscle to be connected to bone. The tendon will fuse with the periosteum that coats the bone. The end result is the pulling of the bone in a specific direction by the muscle. In some cases, the mysia will fuse into a tendon-like sheet known as an aponeurosis. An aponeurosis is what’s seen when rectus abdominis muscles connect to each other as is seen when someone has a “six-pack.”

Skeletal muscle fibers are individual long, cylindrical cells that can be up to thirty centimeters or nearly twelve inches in length as is seen in the sartorius muscle of the leg.

These are multinucleated cells because of their long length. It means that large numbers of proteins and enzymes are necessary for muscle contraction.

The plasma membrane of muscle fibers is called the sarcolemma with the cytoplasm referred to as the sarcoplasm. The smooth endoplasmic reticulum is what stores calcium ions and is what is referred to as the sarcoplasmic reticulum. The functional unit of a muscle fiber is called the sarcomere, which is a highly organized structure consisting of actin (the thin filament) and myosin (the thick filament), along with supportive proteins, troponin and tropomyosin.

The sarcomere is bundled within a myofibril, which contracts, contracting the entire muscle cell. There are hundreds to thousands of myofibrils, each of which contains thousands of sarcomeres within a single muscle fiber with a sarcomere length of two micrometers for each sarcomere. The actin myofilaments are anchored at Z-discs, forming strands called the thin filaments of the sarcomere. Myosin strands or thick strands are not connected to the Z-discs but are lined up along the thin filaments.

The neuromuscular junction is also important. This is where the muscle fiber connects to nervous system. It consists of the motor neuron, the synaptic cleft or space between them, and the motor end plate, which contains the receptors for the neurotransmitter. Muscle cells, like all cells, have an electrical gradient of about -60 to -90 millivolts compared to outside cells. This is the membrane potential of the cell. The membrane potential is controlled by charged particles that differ in charge across the membrane. There are ion channels that control this membrane potential.

The difference between skeletal muscle cells and other cells is that these are electrically excitable cells that can change their membrane potential, called “generating action potentials.” The action potential has the ability to transmit along the cell membrane as a wave that ultimately excites the entire cell. What this process is about is called the excitation-contraction coupling process in which excitation leads to contraction of the muscle.

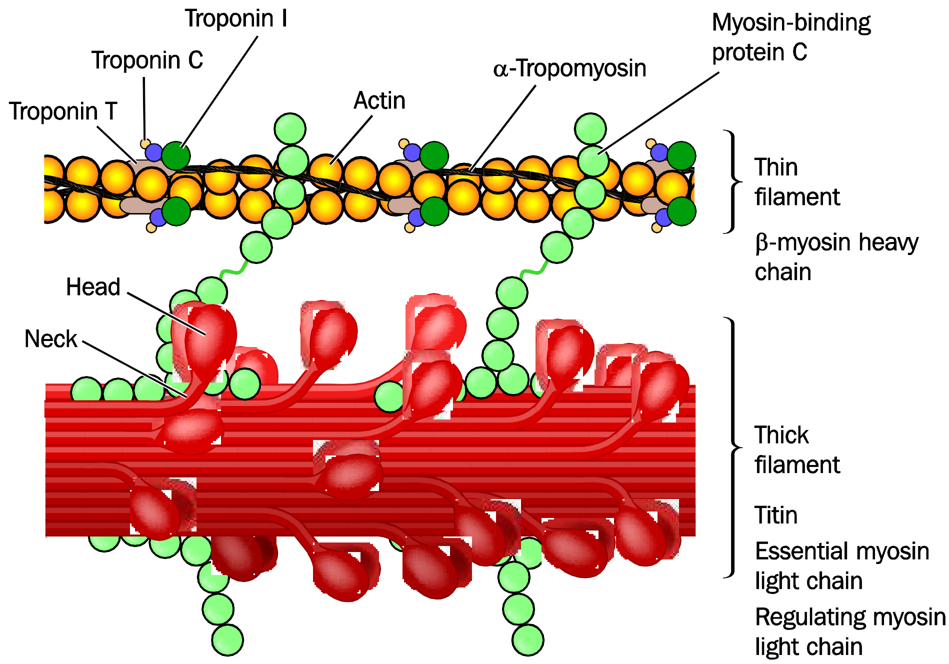
The motor neurons or “nerve cells” originate in the spinal cord with a smaller number located in the brainstem to control contraction of muscles of the face, head, and neck. The processes of these muscle nerve cells, called axons, can transmit the signal from the spinal cord to the individual muscle cells. These axons can be up to three feet long, forming bundles called nerves similar to individual wires bundled in a cable.

When the nerve cell is activated, it releases acetylcholine, its neurotransmitter, that crosses the synaptic cleft, which is the space between the nerve cell and the motor end plate of the muscle cell. It binds to the muscle cell receptors at the motor end plate, causing positively charged ions to pass through the cell membrane, raising the membrane potential so that it is less negative. This is called depolarization. This depolarization triggers the action potential that spreads to all parts of the muscle cell. In the meantime, there is an enzyme called acetylcholinesterase that degrades the acetylcholine so it can no longer act on the motor end plate.

When the muscle cell is activated with an action potential, there are invaginations of the sarcolemma (cell membrane) called T-tubules or transverse tubules. They ensure that the activated membrane can get closer to the sarcoplasmic reticulum. This is where it can affect the calcium transport inside or outside the sarcoplasmic reticulum. The T-tubule with membranes of the sarcoplasmic reticulum on either side is called a triad. The triad surrounds the myofibril, which is what contains actin and myosin.

SEQUENCE OF MUSCLE CONTRACTION EVENTS

In understanding the structure of the muscle fiber, you need to see that the shortening of these long, thin muscle cells involves two kinds of fiber in them, which are actin and myosin. The shortening relies on the presence of calcium ions in the cytoplasm of the muscle cell, which causes un-shielding of actin binding sites, which had been shielded by troponin and tropomyosin. Calcium also activates enzymes that will activate the myosin heads. Figure 3 shows actin and myosin in the muscle cell.



The signal must first be received in order to have muscle contraction. This happens when the neurotransmitter acetylcholine acts on receptors on the motor end plate of the muscle fiber. Each muscle fiber has a motor end plate. The attachment of acetylcholine results in depolarization or change in energy potential across the cell membrane of the muscle fiber because sodium ions enter the cell. It ultimately causes an action potential that spreads down the muscle fiber.

This action potential—an electrical potential across the membrane—triggers the release of calcium ions from their storage in the sarcoplasmic reticulum, which is the specific endoplasmic reticulum within muscle cells. The calcium initiates the contraction, which is sustained by adenosine triphosphate or ATP, which is the energy currency of the muscle cell and indeed, all cells. The muscle will continue to contract as long as ATP is available.

The cessation of muscle contraction starts with signaling from the motor neuron ends, which causes repolarization of the muscle cell, closing the calcium channels in the sarcoplasmic reticulum. The calcium ions are pumped back into the sarcoplasmic reticulum, causing tropomyosin to reshield or recover the actin strands binding strands.

Another thing that can stop muscle contraction is when the muscle cell runs out of ATP, becoming fatigued.

The molecular events of muscle fiber shortening occurs within the sarcomeres themselves. The muscle fiber has thousands of linearly-arranged myofibrils that shorten as the myosin heads pull upon the actin filaments. The region where thick and thin filaments overlap is dense in appearance, with little space between the filaments. As mentioned, the thin filaments are attached by the Z-discs but do not connect in the middle of the myofibril. In the same way, the thick filaments are not connected to the Z-discs but line up between the thin filaments.

The sliding (or contraction) can only happen when the myosin-binding sites on the actin filaments are exposed by steps that start when calcium is released by the sarcoplasmic reticulum. Tropomyosin is the main protein that winds around the chains of actin filaments, covering the binding sites and preventing the contraction from occurring. Tropomyosin forms a complex with troponin that together prevent myosin from binding to actin.

The troponin protein binds to calcium, allowing the tropomyosin to slide away from the myosin binding sites on the actin molecule. Cross-bridges form between the actin and myosin, pulling the actin toward the center of the sarcomere. This is temporary and requires ATP to allow for the pulling of the actin and myosin further along each other. The cross-bridges re-cock and allow the myosin heads to attach to other binding sites further down the actin molecule so that actin and myosin can together contract the myofibril—and the muscle itself.

As actin is pulled, the filaments move approximately 10 nanometers toward the M-line, which is the center line that indicates the center attachment of the myosin molecule. This movement of one part of the myosin molecule down the actin molecule, is called a “power stroke.” Without ATP, only one stroke can happen. The myosin head attachment to actin will not reverse itself and detach without the action of ATP.

Myosin has ATPase activity that converts ATP to ADP and phosphate, releasing the cross-bridge so that the myosin head can be in position for further movement. Many cross-bridges break and re-form on a continuous basis along the molecule, with each thick filament consisting of 300 separate but attached myosin molecules. Interestingly, rigor mortis after death is the result of “running out of ATP molecules,” which are necessary to have actin and myosin separate from each other. This leads to permanent contraction of the muscles.

Muscle Metabolism

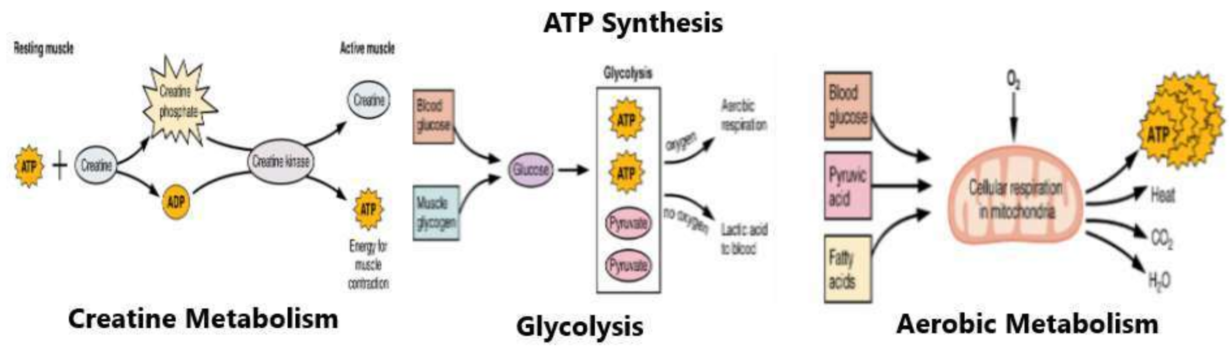
ATP is necessary for muscle contraction and must be available in large numbers for the muscle to function. ATP is necessary for both the actin-myosin contraction and for the active transport of calcium across the sarcoplasmic reticulum. There isn’t much ATP stored in muscle cells—only enough for about one second of a muscle contraction. For this reason, there are multiple mitochondria inside the muscle cell—each of which is a powerhouse for making new ATP molecules.

These are essentially three mechanisms for ATP synthesis in the muscle cell. These are creatine phosphate metabolism, anaerobic metabolism (called glycolysis), and aerobic respiration (in the mitochondria).

Creatine phosphate is a molecule that stores energy inside its phosphate bonds. When the muscle is resting, ATP transfers its energy to creatine in order to make creatine phosphate and ADP. This is the immediate muscle reserve for ATP. It’s the front line for making ATP molecules when the muscle contracts. The creatine phosphate transfers its stored energy back to ADP to make creatine and ATP through the action of the enzyme called creatine kinase. This gives only about 15 seconds of muscle energy.

When ATP is depleted, the muscles will undergo glycolysis, which is an anerobic process, meaning it is independent of oxygen. It is not as quick as creatine phosphate metabolism and involves glucose metabolizing into two pyruvate molecules, leading to the production of two ATP molecules. When oxygen levels are low, the pyruvate becomes lactic acid as an end-product.

If oxygen is available, the pyruvate will go on to the mitochondria to make many more molecules of ATP. Glycolysis can be sustained for one minute so it is useful in facilitating short bursts of energy output. About 95 percent of ATP for the exercising muscle is provided through the activity of aerobic respiration in mitochondria. This is much more efficient and produces 36 ATP molecules per molecule of glucose. It requires a steady input of oxygen, stored in the myoglobin in the muscle cell, allowing for the greatest efficiency of muscle contractions. Figure 4 shows the sources of ATP in the muscle cell:



Aerobic training will increase the efficiency of the circulatory system so that oxygen can be supplied to muscle for longer periods of time. Muscle fatigue happens when the muscle can no longer contract, even after receiving the proper signals from the central nervous system. No one knows exactly what happens to induce muscle fatigue. It probably has something to do with ATP reserves being low as well as increased lactic acid buildup, which may lower the pH of the inside of the cell, affecting the ability of enzymes to function in the muscle cells. Long periods of time in which there is sustained exercise may result in damage to the sarcoplasmic reticulum so that it cannot properly regulate calcium release as would be necessary for muscle contraction.

Because muscles need to function effectively for a period of time, there is a lot of phosphocreatine and a large amount of muscle glycogen in order to fuel the muscle cells so they can participate in ATP synthesis. As mentioned, ATP energy can come from phosphocreatine. Other sources of ATP energy are muscle glycogen (which is the storage form of glucose), nutrients from the circulation, such as fatty acids and glucose, and amino acids (which can come from the circulation as well as inside the muscle fibers themselves).

Intense activity of muscle tissue results in an oxygen debt, which involves the amount of oxygen necessary to compensate for ATP produced without oxygen during exercise. Oxygen is required to restore ATP and creatine phosphate levels, to convert lactic acid back into pyruvate, and to convert lactic acid into glucose or glycogen in the liver. This leads to increased breath rate before and immediately after exercise. This increase in oxygen intake by the body will persist until the oxygen debt has been paid.

Ultimately, the motor neuron will stop releasing acetylcholine into the synaptic cleft at the neuromuscular junction. This results in repolarization of the muscle, which closes the calcium ion gates in the sarcoplasmic reticulum; ATP-dependent pumps will move the calcium back into the sarcoplasmic reticulum. Actin-binding sites on the actin molecule get reshielded and the muscle is allowed to relax again.

The number of actual skeletal muscle fibers in a given muscle is determined genetically and will not change over a person's lifetime. This means that muscle strength is related specifically to the number of sarcomeres and myofibrils in each muscle fiber. Hormones and anabolic steroids acting on the muscle can increase the production of sarcomeres and myofibrils per muscle fiber, leading to hypertrophy of the muscles. Atrophy of the muscles happens when the number of sarcomeres and myofibrils decreases, while the actual number of muscle fibers remains the same.

The relaxation of muscle so that it can return to its original length is referred to as the muscle's elasticity. Muscle also has extensibility, which is the ability to stretch and extend when provoked. Finally, it can have contractility, which is what allows the muscle to shorten from its relaxed state.

There are differences between skeletal muscle and the other muscle types in the human body. Skeletal muscle involves regular arrangement of myofibrils and muscle cells with muscle cells being long and multinucleated. Cardiac muscle fibers have one to two nuclei per muscle fiber cell and there is electrical connection between these muscle cells so that they contract as a unit by forming a syncytium.

Smooth muscle cells are irregularly-aligned and there is just one nucleus per cell. Smooth muscle is called "smooth" because it is not striated. It is the smooth muscles that control the blood pressure and contractility of the blood vessels. Central smooth muscle cells in the major blood vessels will contract to increase the blood pressure, while peripheral blood vessel smooth muscle will relax in order to increase the blood flow necessary to supply oxygen to muscles during exercise. Smooth muscle also supplies the visceral organs in the gastrointestinal tract.

Skeletal muscle will generate heat because of the breakdown of ATP. Whenever ATP is broken down, heat is produced. This heat is easily noticed during exercise, particularly when there is sustained muscle contraction. When there is extreme cold, muscles will shiver due to random skeletal muscle contractions. This shivering expends ATP energy and produces heat necessary to keep the body warm when it is challenged by a cold environment.

Types of Muscle Fibers

There are three different types of muscle fibers in the human body. There are slow oxidative fibers or SO fibers that contract relatively slowly, using the process of aerobic respiration in order to produce ATP. There are also fast oxidative fibers or FO fibers that contract quickly and use both aerobic and anaerobic (glycolytic) respiration. These tend fatigue more quickly than SO fibers. Finally, there are fast glycolytic fibers or FG fibers that have fast contractions but use anaerobic glycolysis to gain energy. These muscles fatigue the fastest. You should know that humans contain different proportions of these types of muscles.

The speed of contraction will depend on how quickly the ATPase associated with the myosin molecule can cross-bridge and reload. Fast fibers will hydrolyze ATP approximately twice as quickly as slow fibers, resulting in a much quicker cycling process. If a fiber uses ATP made by aerobic pathways, it is considered oxidative. This will be a fiber that is more resistant to fatig0ue. Glycolytic fibers will use ATP made by glycolysis, which does not require oxygen, work more quickly, and fatigue the fastest.

The oxidative fibers will contain more mitochondria than glycolytic fibers because these organelles are the source of ATP energy used by these cells. On the other hand, these tend to be small diameter muscle cells that do not produce a large amount of tension. There is intense blood supply to these cells and a greater amount of myoglobin, which houses the oxygen necessary for these cells. This is why these fibers are called “red muscle.”

These SO fibers or slow oxidative fibers can function for a long period of time, producing isometric contractions that stabilize bones and joints, as well as contractions that happen on a regular basis. They are not used for powerful and fast movement that require rapid cross-bridge cycling. The FO fibers or fast oxidative fibers are considered intermediate fibers that will produce ATP more quickly than slow oxidative fibers and also have high amounts of mitochondria. They do not have a lot of myoglobin in them so their color is lighter. FO fibers are used for walking and other movement but are not good for explosive movement.

FG or fast glycolytic fibers use anaerobic glycolysis as the main source of ATP. Their diameter is large and there is a lot of glycogen in these fibers. There are not a lot of mitochondria in these fibers and not a lot of myoglobin so they are called white muscle fibers. They are good for quick and powerful movements but fatigue quickly. Note that most major muscles will have a mixture of each type of fiber with the predominant fiber type in a muscle determining the primary function of the specific muscle in question.

Red muscle fibers are “slow” fibers that are activated when cycling, marathon running, swimming, and in muscle tone maintenance. Their main energy source is beta-oxidation of fatty acids. As the intensity of the exercise increases, there will be increased muscle dependence on carbohydrates as an energy source.

White muscle fibers are “fast” fibers that are rich in the enzymes that participate in glycolysis as well as in glycogen itself. This is the type of muscle fiber used in sprinting and weight-lifting. The biggest danger of this type of exercise is that it builds up lactic acid, resulting in the fatigue and muscle pain seen when the activity goes on too long. Lactate will be released from these muscles into the bloodstream, where it is carried to the liver in order to be converted back into glucose in a process called the gluconeogenesis. This is called the Cori cycle and allows lactate to serve as an energy source for the body.

Hormones will affect this type of muscle metabolism in various ways. Insulin will increase the entry of glucose and fatty acids into the muscle cells, which explains why diabetics have difficulty with muscle metabolism. Insulin also activates the anabolic processes in the body, which allows for the formation of proteins, glycogen, and triglycerides (which store fat). On the reverse side is catecholamine activity, which activates glycogenolysis in the muscle as well as lipolysis.

Neural Control of Muscles in Exercise

In order to move a load, the sarcomeres need to shorten. This shortening force is called muscle tension. This leads to two types of skeletal muscle contractions, which are isotonic and isometric contractions. In isotonic contractions, the muscle shortens and stays constant. There are two types of isotonic contractions, which are concentric and eccentric. Concentric contractions involve the shortening of the muscle in response to the load. Eccentric contraction occurs when the muscle tension decreases and the muscle lengthens. These are used for movement and balance in the body.

Isometric contractions occur as the muscle produces tension without actually changing the angle of the skeletal joint. There is sarcomere shortening and muscle tension that cannot overcome the weight of the load. This happens when lifting a heavy load. Most actions of the body are a combination of isotonic and isometric contractions that together produce a wide range of possible outcomes.

As you remember, every skeletal muscle fiber needs to have innervation by the axon terminal of a motor neuron in order to engage in the process of contraction. The group of muscle fibers that are innervated by a single motor neuron is referred to as a motor unit. The actual size of a motor unit depends on what the muscle is used for. Small motor units permit fine motor control. This is seen particularly in facial muscles. Extraocular muscles have six fibers per motor unit. The large motor units are seen when gross or large movements are necessary.

The smaller motor units will have lower-threshold motor neurons that are more excitable and that fire to small numbers of muscle fibers. There will be the resultant small degree of tension on the muscle. When more strength is needed, the larger motor units, which have a higher threshold of activation, will become active, resulting in an increase in muscle contraction called recruitment. Recruitment increases the strength of the muscle. This is how the nervous system controls the strength of a given muscle.

There is a relationship between the length of a sarcomere and the tension that can be created by the muscle. When a muscle fiber contracts, it can only contract over the space where the thick and thin filaments already overlap. This means that the total length of the sarcomere has a direct influence on the force that can be generated. This relationship is called the length-tension relationship.

The ideal length of a sarcomere necessary to produce maximal tension occurs at 80 to 120 percent of its resting length or about 100 percent. This will maximize the overlap of the of actin-binding sites and myosin heads. If the sarcomere is stretched beyond 120 percent, there is poor overlap of the thick and thin filaments. If the sarcomere is shortened less than 80 percent, the zone of overlap is insufficient. If the muscle is stretched to where the thick and thin filaments don't overlap, no cross-bridges can form. This generally does not occur because there is connective tissue that supports the muscle fiber.

A single action potential sent from a motor neuron will cause a twitch of the muscle, which can be short or long, depending on the type of muscle. The tension produced by a single twitch can be measured in an electromyogram, which measures tension over time. There are three phases to any twitch. The first is the latent phase, which involves calcium release by the sarcoplasmic reticulum and propagation of the action potential. There is no actual contraction. This is followed by the contraction phase, where the sarcomere is actively shortening. The relaxation phase is last, when the tension is decreased and calcium ions are pumped back into the sarcoplasmic reticulum.

It actually takes a series of action potentials to produce a muscle contraction that will produce work. Muscle contraction is normally more sustained and modifiable by input from the nervous system in what's called a graded muscle response. It takes both a high-enough frequency of action potentials and a higher number of motor neurons transmitting action potentials to affect the actual tension produced by the muscle. The second action potential will add to the first in a process called "wave summation." The process of tetanus happens when there is sustained muscle contraction over time.

When a skeletal muscle has been dormant for a prolonged period of time and then activated, the initial contractions will generate half the force of later contractions. This tension will increase in a graded manner over time in a stepwise fashion known as treppe. In this process, the muscle contractions become more efficient. The phenomenon of treppe results from a higher concentration of calcium ions in the sarcoplasm that can only occur when there is enough ATP in the muscle cell.

There is rarely a time when the muscles are completely relaxed. There will always be some amount of tension necessary to maintain its contractile proteins. This is called muscle tone. This requires a complex interaction between the nervous system and skeletal muscle so that few motor units get activated at a time, which allows some motor units to recover while others are active.

A lack of low-level contractions is referred to as hypotonia, which may occur when the CNS is damaged in some way. It can also happen if there is a loss of innervation to skeletal muscle. Hypotonic muscles will appear flaccid and will have weak reflexes. Excessive muscle tone is referred to as hypertonia, which is often accompanied by hyperreflexia. Hypertonia can be displayed as spasticity or muscle rigidity as is seen in Parkinson's disease.

Energy Expenditure and Muscle Adaptation to Exercise

Physical training alters the appearance of skeletal muscle, changing muscle performance. In the same way, a lack of muscle use can result in decreased performance and a change in muscle appearance. Hypertrophy involves an addition of structural proteins to a muscle fiber, while increasing the cell diameter. The reverse occurs when structural proteins are decreased as well as the muscle mass; this is called atrophy. Age-related atrophy of the muscles is called sarcopenia.

Slow fibers are predominant in endurance exercises that require little force but will require numerous repetitions. These fibers will involve aerobic metabolism that allows for the maintenance of contractions over long periods of time. What endurance training does is modify these slow fibers to make them even more efficient by allowing for increased numbers of mitochondria and myoglobin in the muscle cell.

Aerobic training will also result in an increase in capillaries around the muscle fiber, which is referred to as angiogenesis. These capillaries supply oxygen and remove metabolic waste, supplying nutrients to deep portions of the muscle. It does not greatly increase the mass of the muscle and allow the muscle to sustain itself for longer periods of time. The muscles that have a high proportion of slow oxidation muscles will benefit most from endurance activity.

Resistance training requires a large number of fast glycolytic fibers to produce short, more powerful movements. There is a high rate of ATP hydrolysis and strong cross-bridges that result in more powerful muscle contractions. Resistance trainers will have a high ratio of FG fibers to SO fibers in keeping with the force of contractions required. The muscles will thicken and hypertrophy as a result of this type of training. Interestingly, there isn't the increase in mitochondria or capillary density seen with endurance training. Connective tissue and tendon strength will increase as this resistance training proceeds.

For effective strength training, the intensity of the exercise must be increased on a continual basis. The weight lifter must lift increased weights in order to increase muscle size. This is called "increasing the load." If done improperly, resistance training can lead to overuse injuries of the tendons, muscles, or bone. These injuries can happen if the load is too heavy or if the muscles aren't rested enough to recover between workouts.

Muscles will increase their strength and size when they become forced to contract at near-maximal tensions. Muscles need to overload in order to hypertrophy and become stronger. There needs to be increased protein synthesis and decreased protein degradation in order to have muscle hypertrophy. Fast fibers will increase the rate of protein synthesis, while slow fibers will decrease the rate of protein degradation. Amino acid uptake occurs to a greater degree when muscles are at their highest level of contraction.

Proper rest intervals are necessary for maximizing muscle tension between exercises and during training sessions. Insufficient rest leads to poor recovery and decreased muscle capacity. Most athletes will do strength training three to four times a week; however, large muscle exercises are done no more often than twice a week. This is completely empiric but appears to be enough to have adequate recovery between sessions.

There will be specificity between the nature of the exercise and the adaptation of the muscle. For example, if an athlete decides to strength-train the leg muscles, the leg muscles will hypertrophy and not any other muscles. The different muscle types have characteristic contractile properties as you have seen. The low-threshold muscles are the slow twitch fibers, used for jogging and the basic activities of daily living. High-intensity activities and high-speed activities all require recruitment of fast twitch motor units.

As mentioned, there are individual differences between the fast twitch to slow twitch ratio in athletes that excel in certain areas of athletics. Endurance athletes will have more slow-twitch, SO muscle fibers, while sprinters and weight trainers will have more fast-twitch, FG muscle fibers. This is genetically determined. On the other hand, there are benefits from training irrespective of a person's genetics such that good training can help make up for some differences in an athlete's genetic makeup.

Key Takeaways

- Muscle contraction involves the sliding of actin and myosin proteins in the myofibril.
- The signal to each muscle happens with a motor neuron acting on each muscle fiber.
- There are different types of muscle fibers that vary in their use of specific metabolic pathways.
- ATP is necessary at every aspect of muscle fiber function and is necessary to allow for the cocking and uncocking of the myosin heads and actin-binding sites in the myofibril.
- The training process will result in changes that affect the slow-twitch and fast-twitch muscles differently.
- Athletes will have genetically-determined ratios of fast to slow twitching muscles.

QUIZ

1. Muscle contraction requires the sliding of what two proteins along each other?

    a. Troponin and tropomyosin
    b. Actin and myosin
    c. Actin and troponin
    d. Myosin and tropomyosin

    Answer: b. Each of these is a protein that acts to contract muscle; however, it is the actin and myosin that slides along each other to create muscle contraction.

2. Which ion is directly responsible for muscle contraction by being released from the sarcoplasmic reticulum in muscle cells?

    a. Calcium
    b. Potassium
    c. Sodium
    d. Phosphorus

    Answer: a. Calcium is released from the sarcoplasmic reticulum in muscle cells after an action potential is triggered across the muscle cell membrane. This release of calcium causes unshielding of muscle proteins that allow for muscle contraction.

3. What are the invaginations of the cell membrane called that extend inward to surround the sarcoplasmic reticulum of the muscle cell?

    a. T-tubules
    b. Z-lines
    c. Triads
    d. Motor end plates

    Answer: a. The T-tubules are invaginations of the sarcolemma that extend inward to surround the sarcoplasmic reticulum so as to affect the activity of the sarcolemma during the contraction process. They participate in the excitation-contraction process.

4. Which molecule in the myofibril has “heads” that attach to other molecules in the act of contracting the myofibril?
   a. ATP
   b. Myosin
   c. Actin
   d. Tropomyosin

   Answer: b. The myosin molecule consists of myosin heads that reach out to the actin molecule in the myofibril, binding to the actin and causing the pull of actin and myosin together, making the myofibril contract.

5. About how long will glycolysis provide muscle energy or ATP energy to the exercising muscle after initiation of muscle activity in the absence of oxygen?
   a. 5 seconds
   b. 1 minute
   c. 30 minutes
   d. Indefinitely

   Answer: b. One minute is just about the length of time energy can be produced with glycolysis only and no aerobic input. It takes aerobic input to have longer periods of muscle contraction in the exercise process.

6. What aspect of the muscle remains the same when a person builds muscle mass, as would be the case with weight lifting?
   a. Myofibril number
   b. Sarcomere number
   c. Actin molecule number
   d. Muscle fiber number

Answer: d. A person is born with the number of muscle fibers that they are going to have and this does not change with exercise and weight training. However, the number of myofibrils, sarcomeres, and actin molecules do change.

7. Which muscle fibers are considered "red" muscle fibers because they have large amounts of myoglobin in the cell?

   a. Fast glycolytic fibers
   b. Fast oxidative fibers
   c. Slow oxidative fibers
   d. Slow glycolytic fibers

   Answer: c. Slow oxidative fibers will contain a lot of myoglobin. This facilitates a sufficient supply of oxygen, thus allowing the larger number of mitochondria to participate in aerobic metabolism.

8. Which makes a white muscle fiber white in color?

   a. Large amounts of myoglobin
   b. Large numbers of mitochondria
   c. Low levels of glycogen
   d. Low myoglobin concentration

   Answer: d. The low myoglobin concentrations will mean the muscle fiber is white in color. These will be fast glycolytic muscle cell fibers that react explosively but do not last for very long.

9. Which hormone is most responsible for providing energy input to the muscle cells from the bloodstream?

   a. Insulin
   b. Glucagon
   c. Epinephrine
   d. Cortisol

   Answer: a. Insulin is responsible for taking exterior forms of energy, like glucose and amino acids, and putting them in the muscle cells.

10. Which type of muscle contraction is linked to muscle contraction but no change in the angle of the joint?

a. Isometric contraction
b. Eccentric contraction
c. Isotonic contraction
d. Concentric contraction

Answer: c. Isotonic contractions occur without a change in the angle of a joint. This is different from isometric contractions—both eccentric and concentric—that do involve a change in the angle of the affected joint.

Chapter 2: Cardiovascular System and Exercise

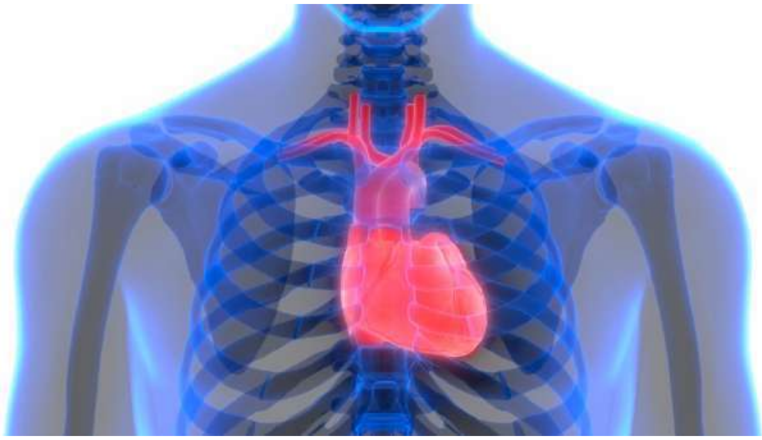
This chapter discusses the anatomy and physiology of the heart and how the cardiovascular system responds to exercise. Similar to the statement that no exercise can happen without muscle function, the heart and the blood vessels supplying muscle tissue are vital to participating in any sporting activity. Most exercise—in particular aerobic activities—involves the proper response of the heart and blood vessels to the act of exercising. There is a great deal of stress placed upon the heart during any physical activity, making it a vital organ of study for the exercise physiologist.

Anatomy of the Heart

At rest, the heart beats at an average of 75 contractions per minute, which means it contracts about 108,000 times daily and nearly three billion times during a person's average lifespan. Each major pumping chamber of the heart will eject 70 milliliters of blood per contraction, sending 10 million liters of blood through about 60,000 miles of blood vessels each year.

The heart is the sole pump of the blood in the body, located in the mediastinum, which is the space between the lungs and slightly toward the front of the chest cavity. The heart is held in the pericardial cavity, which is a space bound by a tough connective tissue sac called the pericardium or pericardial sac. There are several great vessels exiting and entering the heart at its base, which is near the top of the heart at the level of the third rib. The tip of the heart is also referred to as its apex, lying between the third and fourth rib.

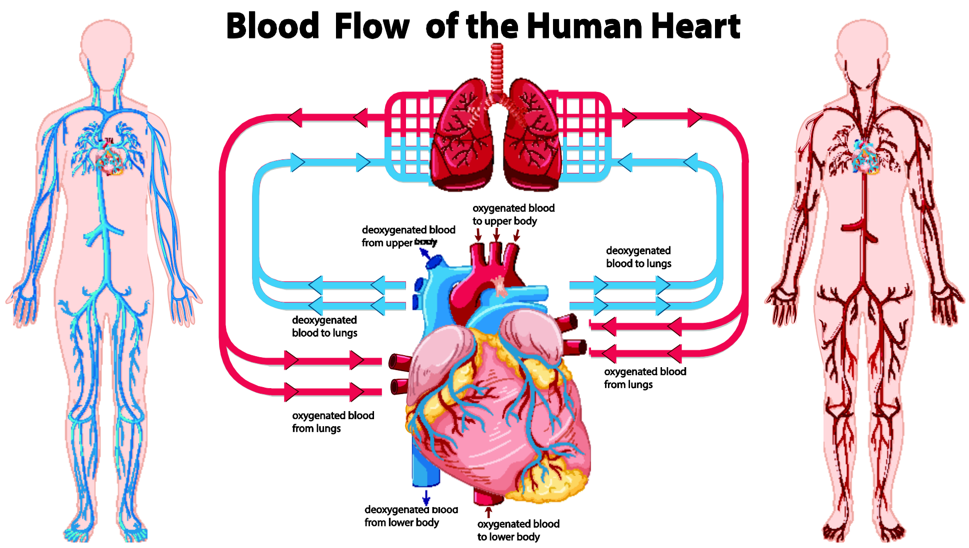
The right side of the heart is tipped toward the anterior of the heart and the left side of the heart is tipped toward the posterior of the heart. The apex of the heart is slightly deviated, sitting in a space or depression in the medial surface of the inferior lobe of the left lung—a depression called the cardiac notch. Figure 5 shows the anatomy of the heart as it sits in the chest cavity:



As you can see, the heart is shaped much like a pinecone, which is broad at its base and tapers to the apex. Typically, it is considered to be the size of a fist with the weight of the heart being 250-300 grams in females and 300-350 grams in males. The effect of exercise on the well-trained individual is an increase in heart mass, as it is "exercised" along with the rest of the body. This hypertrophy of the heart does not increase muscle fiber numbers but increases the size of muscle fibers.

You should know that, while an increase in heart size will help the heart pump more effectively, it does not necessarily follow that all enlarged hearts will be the result of exercise. In hypertrophic cardiomyopathy, the heart is enlarged and may cause sudden cardiac death in some athletes. In other cases, the heart chambers are enlarged, giving the heart an overall increase in size but with a decreased efficiency in the pumping action of the heart.

There are four chambers to the heart, separated into two right-sided and two left-sided chambers. There is a right atrium, right ventricle, left atrium, and left ventricle. The atria are the two receiving chambers and the ventricles are the two pumping chambers. These lead to two different circuits or "circulations" involved. These are the pulmonary and systemic circuits. Figure 6 shows the anatomy and circulatory systems in the body:



The pulmonary circulation or the "right side" of the heart involves the right atrium receiving blood from the body, transferring it to the right ventricle, and sending it to the lungs. The systemic circulation involves the left atrium receiving blood from the lungs, the right side of the heart handles deoxygenated blood and the left side of the heart handles oxygenated blood.

The right ventricle pumps deoxygenated blood into the blood vessel known as the pulmonary trunk, which leads toward the lungs, quickly bifurcating or separating into the left and right pulmonary arteries. These are the only arteries in the body containing deoxygenated blood. These vessels branch many times before reaching the pulmonary capillaries, which is where gas exchange occurs in the lungs. In gas exchange, carbon dioxide exits the blood into the alveoli (air sacs) of the lungs, while oxygen enters the capillaries. Blood returns to the left side of the heart via the pulmonary veins, which contain oxygenated blood.

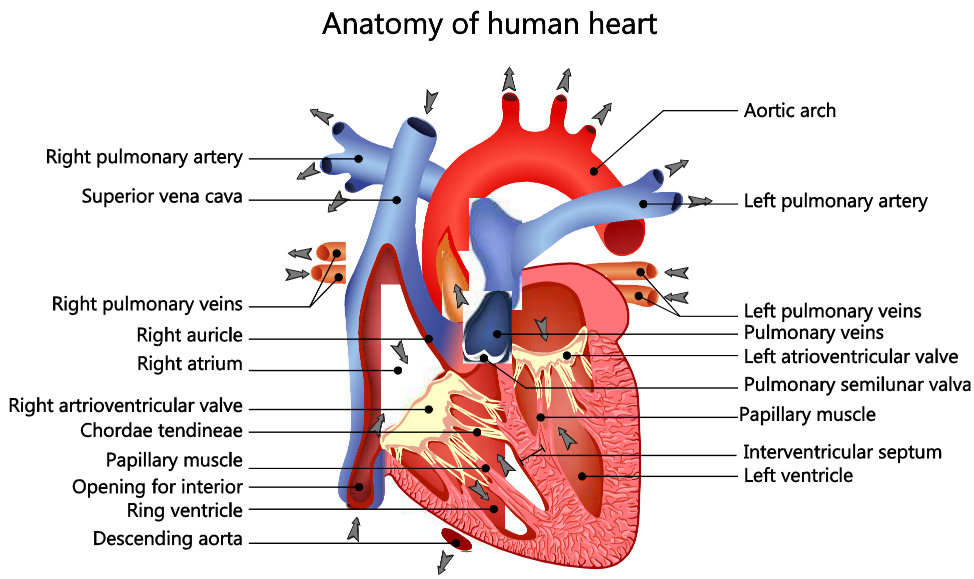
The left side or left ventricle takes oxygenated blood that it receives from the left atrium, sending it to the aorta, which divides into many arteries and smaller arterioles until they reach the systemic capillaries, where oxygen enters the tissues and carbon dioxide leaves the tissues. This leads to blood entering the venules and larger veins, ending in the superior and inferior vena cava, which are large veins that enter the right atrium, completing the circulatory process.

Internal Heart Structures

There are several septa (plural for septum or wall) that separate the different chambers. Between the two atria is the interatrial septum. This contains the fossa ovalis, which is an oval depression that was once an opening between the chambers called the foramen ovale. The foramen ovale was necessary in the fetus allowing blood to bypass the unnecessary pulmonary circuit in the uterus. The septum primum is the flap that closes shortly after birth in order to separate the chambers completely.

Between the two ventricles is the interventricular septum, which is much thicker than the interatrial septum and contains important electrical pathways from the atria to the ventricles. Between the atria and ventricles is the atrioventricular septum. It is this septum that contains the important valves that separate the chambers of the heart. The two atrioventricular valves are the tricuspid valve (between the right atrium and the right ventricle) and the mitral valve (between the left atrium and the left ventricle).

The semilunar valves are the valves that exit the heart. There is the pulmonic valve that exits the right ventricle to the lungs, while the aortic valve exits the left ventricle to the aorta. Figure 7 shows these valves and the internal structure of the chambers of the heart:



These valves put tremendous pressure on the heart, leading to the natural necessity of having the presence of connective tissue in order to support the heart. This dense connective tissue in the heart is referred to as the “cardiac skeleton.” The cardiac skeleton contains four rings that surround the openings between the atria and the ventricles, as well as the openings for the valves leaving the heart. The cardiac skeleton itself does not conduct electricity but serves to “funnel” the electrical activity through the heart.

The right atrium receives blood from the coronary sinus, which is the large coronary vein that is made from the superior vena cava (which drains blood from the upper part of the body) and the inferior vena cava (which drains blood from the lower part of the body). There is a prominent ridge of muscles called the pectinate muscles in the right atrium, located in the anterior part of the atrium. Blood is received in a continuous basis from the body to this atrial chamber. There is some contractility of the right atrium as it pumps blood into the right ventricle through the tricuspid valve.

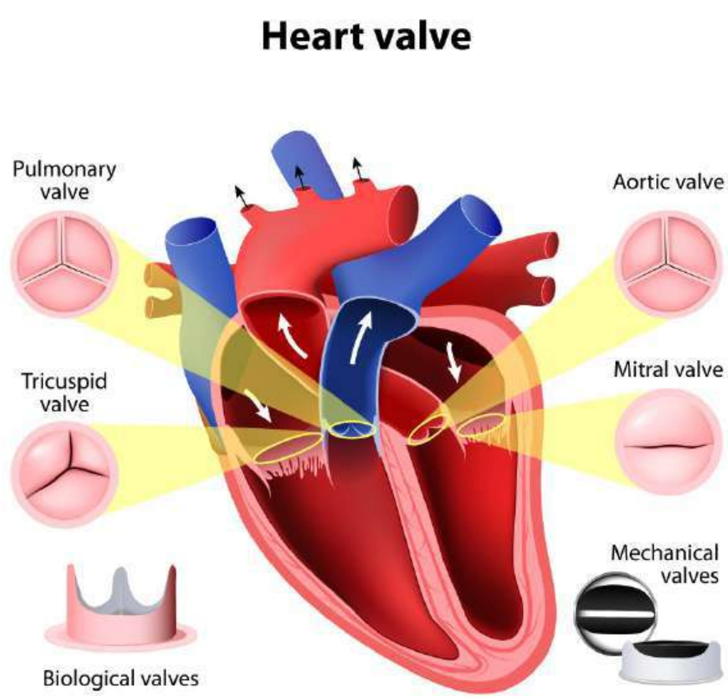
There are strong connective tissue bands, called chordae tendinae, that connect the valve to the right ventricular wall. These are slightly elastic but mostly made of inflexible collagen, connecting the valve to papillary muscles that extend outward from the inferior ventricular surface. There are three major papillary muscles in the right ventricle that correspond to the three leaflets of the valve. These papillary muscles are called the anterior, posterior, and septal papillary muscles. These muscles contract to prevent the backflow of blood back into the right atrium when the right ventricle contracts itself.

There are ridges of cardiac muscle lining the walls of the right ventricle, called trabeculae carneae, that are joined by a thick band called the moderator band that gives the right ventricle its thickness. Blood is pumped from this ventricle by contraction of its musculature through the pulmonary semilunar valve or the “pulmonic valve.” This valve will prevent backflow into the ventricle after it passes through to the lungs.

The blood that enters the left atrium is highly oxygenated from the lungs and comes from four separate pulmonary veins. There are no pectinate muscles in the left atrium itself but there are a few ridges of muscles in the auricle, which is an extension of the atrium. As with the right atrium, blood flows continually into this chamber. There will be contraction of the left atrium at the end of ventricular relaxation that pumps blood into the left ventricle, accounting for 20 percent of ventricular filling. The mitral valve separates the left atrium and left ventricle.

While both sides of the heart, by necessity, must pump the same quantity of blood, the muscular layer is much thicker in the left ventricle when compared to the right ventricle. There are trabeculae carneae in the left ventricle; however, it lacks a moderator band. There are chordae tendinae in this chamber that attach to the mitral valve, preventing backflow of blood into the left atrium. There are just two papillary muscles on this side as opposed to the three papillary muscles on the right side of the heart.

Of the four valves, only the mitral valve is a bicuspid valve. The tricuspid valve, the aortic valve, and the pulmonic valve each have three leaflets, although some people have a heart defect in which one or more valve leaflets is fused, particularly the aortic valve, which can result in damage to the valves and problems with leakage and narrowing of the valves. Figure 8 shows the shape and location of these valves:



When listening to the heart sounds in a healthy person, there will be two heart sound noted, making the typical “lub-dub” sound of the normal heart. The first heart sound, called S1, happens when the two atrioventricular valves close sharply and blood exits the heart. The second heart sound, called S2, happens when the two semilunar valves (pulmonic and aortic valve) close sharply, allowing for filling of the ventricles. Murmurs or “heart murmurs” are heard when there is a restriction of flow through a valve that is too narrow or when there is backflow or “regurgitation” through a valve that is leaky.

Membranes and Layers around the Heart

The pericardium is a firm connective tissue layer that encloses the pericardial cavity. It surrounds the major vessels close to the heart so as to completely close the cavity. There are several components to the pericardium. The outermost layer is the fibrous pericardium, which is tough and dense. The inner layer is the serous pericardium, which is more delicate in appearance. There are two parts to the serous pericardium. These are the parietal pericardium, which is fused to the serous pericardium and the visceral pericardium or “epicardium,” which is fused to the heart. The visceral serous membrane contains a simple layer called the mesothelium, which secretes the lubricating fluid that fills the pericardial cavity.

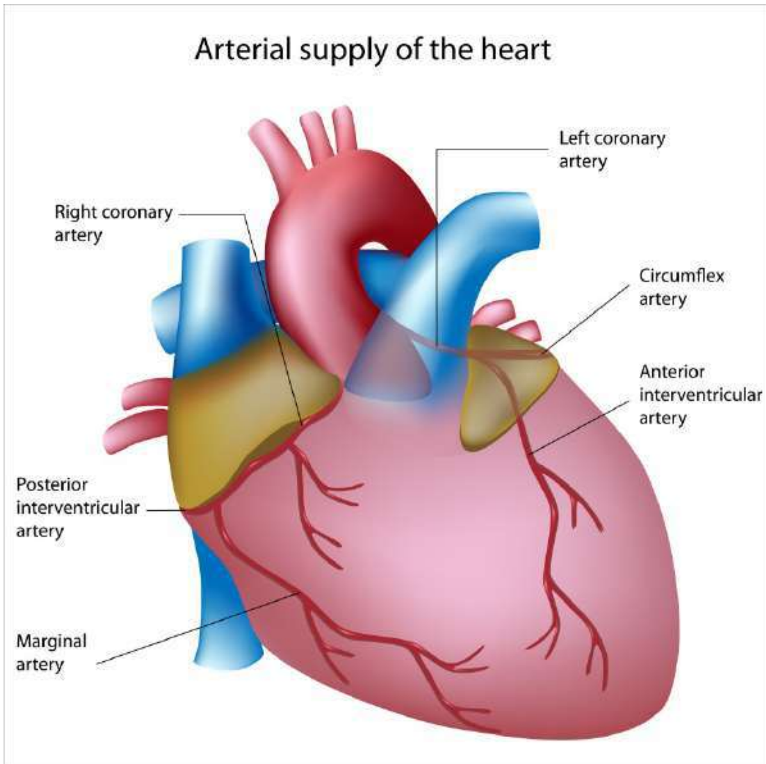
Inside the pericardium, there are prominent fat-filled grooves, each of which is called a sulcus, on the outer surfaces of the heart. The major coronary blood vessels will travel within these sulci. The deep coronary sulcus can be found between the atria and the ventricles. Between the left and right ventricles are two sulci, called the anterior and posterior interventricular sulcus.

The heart itself is made from layers that are not equal in thickness. These are the epicardium, the myocardium, and the endocardium. The epicardium is a part of the pericardial sac that happens to be fused with the heart. The thickest middle layer is the myocardium or “muscle” layer. It consists mainly of cardiac muscle fibers, built on a framework of collagen and blood vessels that supply this part of the heart. The myocardium consists of an interlacing pattern of muscle fibers that together pump blood out of the heart. The left-sided myocardium is thicker because it needs to overcome the higher resistance of the systemic circulation versus the lower resistance of the pulmonary circulation.

There is an innermost layer of the heart wall, called the endothelium, which is joined to the myocardium by a thin layer of connective tissue. There is just one layer in the innermost aspect of the endocardium, called the endothelium, which happens to be continuous with the endothelial lining on the inner aspect of the blood vessels exiting and entering the heart.

The cardiomyocyte is the name given to the cardiac muscle cell. It requires a steady supply of nutrients and oxygen in order to pump on a regular basis. This important need is more necessary for heart muscle cells than it may be for other cells because these cells are ceaseless in their activity. The coronary circulation to these cells is not a continuous phenomenon; rather, it is cyclic so that it peaks when the heart muscle is relaxed and stops when the heart is contracting.

One of the features of the coronary arteries supplying the heart is that there is not a great deal of overlap between the flow distribution of one artery and that of another artery. It means that damage to these arteries is more likely to result in myocardial damage when compared to other arteries. These arteries initially originate just outside of the heart in the dilations or sinuses of the aorta. The left posterior and anterior sinus give rise to the left and right coronary arteries, respectively. The third sinus, the right posterior aortic sinus, does not itself have a vessel linked to it. Figure 9 shows the coronary arteries of the heart:



There are epicardial coronary arteries that remain on the surface of the heart and follow the sulci previously mentioned. The left coronary artery sends blood to the left ventricle of the heart, along with the left atrium and the interventricular septum. The circumflex artery will arise from the left coronary artery and will wind around to the back of the heart. The left anterior descending artery or LAD is a large branch descending down the front of the heart.

The right coronary artery proceeds along the coronary sulcus and distributes blood to the right atrium, parts of both ventricles, and the important heart conduction system. There are marginal artery branches that supply the underside of the heart. There is also a branch called the posterior interventricular artery or posterior descending artery, that supplies much of the back of the heart.

The coronary veins will drain the blood from the heart. They tend to lie in parallel with the coronary arteries. The great cardiac vein can be seen in the interventricular sulcus, eventually flowing along the coronary sulcus into the coronary sinus behind the heart. Most of the vessels drain into the coronary sinuses, although at least one will drain directly into the right atrium itself.

PHYSIOLOGY OF THE HEART

We have talked about cardiac muscle and its similarities to skeletal muscle. One of the biggest differences between these two types of muscle is the fact that cardiac muscle has autorhythmicity. What this means is that it can initiate an electrical potential at a fixed rate that, because the muscle is a syncytium of connected muscle fibers, will pass from one fiber to the next so that the heart contracts as a unit. There are nervous system and endocrine factors controlling the actual rate of autorhythmicity.

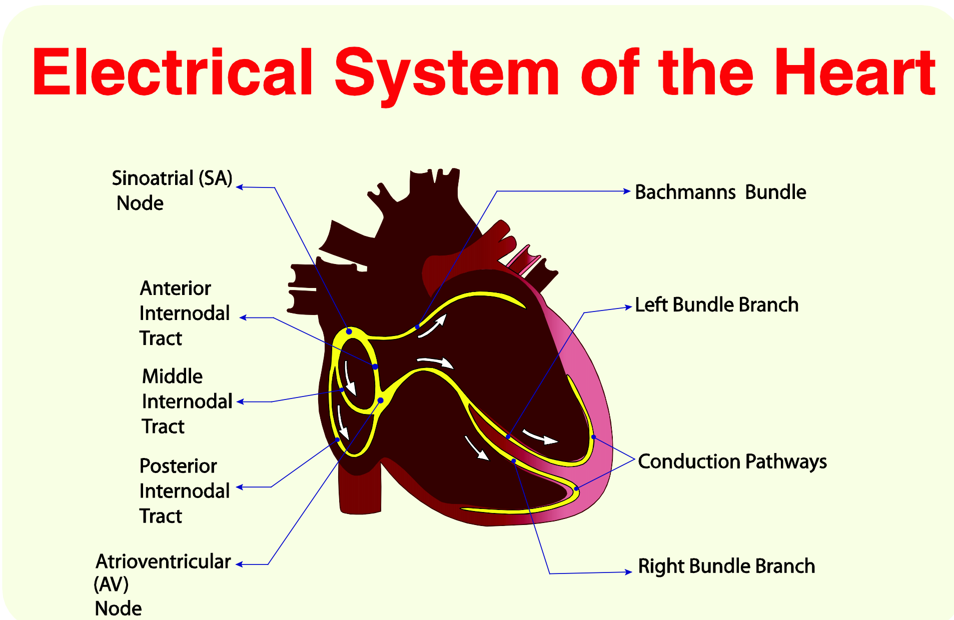
Two types of cardiac muscle cells, including contractile and conducting cells. About 99 percent of the cells are contractile cells. They will be the major cells that do the work of the heart muscle. The remaining cells are conducting cells, which form the conduction system of the heart. These cells do not contract significantly but do have the ability to maintain the electrical signal of the heart.

In general, cardiac muscle cells are much shorter and thinner than skeletal muscle cells. They will have similar striations as are seen in skeletal muscle with myofilaments and myofibrils that are organized in sarcomeres. T-tubules are similar; however, they are only found at the Z-discs. This means they are only one-half as plentiful as the T-tubules in skeletal muscle. Most of the calcium ions come from outside the cell, which is easier to do because they are thinner than skeletal muscle. There are only one to two nuclei per cardiac muscle cell.

There is a great deal of branching in cardiac muscle cells, with adjoining cells connected by intercalating discs that support the synchronized contraction of the heart. What it means is that the cell membranes of two cardiac muscle cells will be joined at these discs, providing for the passage of ions between cells. Because these cells contract forcefully, they need connective tissue between them as well in order to hold them together.

Cardiac muscle is primarily aerobic so that carbohydrates and lipids are the main energy sources. There is plenty of myoglobin, glycogen, and lipids that help to maintain the energy and oxygen these muscles need. There is a long refractory period for these cells because they need to be prevented from tetany. As you might suspect, muscle tetany in cardiac muscle is not compatible with life.

Research has shown a remarkable degree of synchronicity and autorhythmicity of heart muscle cells. Cells with a faster rate of rhythmicity will impact those that have a lesser rate of rhythmicity. This leads to certain parts of the heart having an inherent ability to contract other cells because they contract at a faster rate. In order of decreasing rate of rhythmicity, these areas include the sinoatrial node or SA node, the atrioventricular node or AV node, the atrioventricular bundle (or the bundle of His), the AV bundle branches, and the Purkinje cells. Figure 10 shows the conduction system of the heart:



The sinoatrial or SA node is the normal pacemaker of the healthy heart, having a rate of between 80 and 100 beats per minute. It is located in the upper portion of the right atrium near the opening of the superior vena cava. Because it has the fastest rate of depolarization, it will initiate the sinus rhythm of the heart. The impulse spreads via internodal pathways to the contractile cells of the atrium and the AV node. The impulse takes 50 milliseconds to travel between these nodes. There is also a band called the interatrial band or the Bachmann’s bundle that connects the two atria together. The cardiac skeleton funnels the impulse through these two nodes and prevents a direct impulse connection between the atria and ventricles.

The atrioventricular or AV node is another clump of specialized conductive cells. It is located at the lower margin of the right atrium within the atrioventricular septum. The septum stops the impulse from getting directly to the ventricles without going through the AV node first. The node has a delay making it slow the impulse through the heart. It takes 100 milliseconds for the impulse to pass through the node. Its maximum impulse perpetuation is 220 beats per minute, which established the maximum heart rate possible in a healthy exercising individual. Rates higher than this will impact the contractility of the heart.

Beyond the AV node are the bundle of His, the bundle branches, and the Purkinje fibers. These start down the interventricular septum and divide into two bundle branches referred to as the left and right bundle branches. The left bundle branch is larger than the right one as it supplies the larger left ventricular muscle mass. The papillary muscles contract slightly before the ventricles so they can seal off the atrioventricular valves, preventing leakage from these valves. The Purkinje fibers receive the signal last with a total passage time of 25 milliseconds between the AV node and the ventricles.

The Purkinje fibers spread the impulse across the ventricles. They conduct very quickly compared to other cells of the heart, mainly because of their small size. They are able to conduct the impulse throughout the entire ventricular system in just 75 milliseconds. They essentially squeeze the heart's contraction force from the bottom of the heart to the top of the ventricles. This leads to a total length of initiation by the SA node to the ventricles of about 225 milliseconds.

Action potentials are different between the conductive and contractile cells of the heart. Sodium, potassium, and calcium are crucial for the functioning of these cells. The biggest difference is that conductive cells do not have a stable resting potential. This is because there is a slow influx of sodium into the cells, resulting in spontaneous depolarization. This leads to calcium entering the cell, which further depolarizes it. The potassium then leaves the cell so that there is repolarization again.

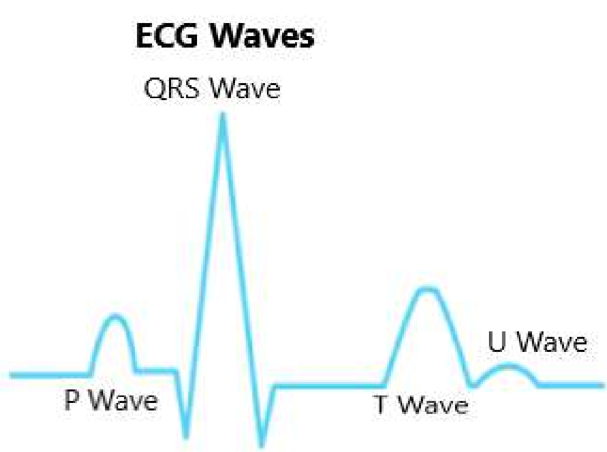
In contractile cells, there will be rapid depolarization, followed by a plateau period and repolarization. This accounts for the long refractory periods necessary for the cells to pump effectively before they can fire again for another time. They do not initiate their own electrical potential, although they can if necessary. They prefer, however, to wait for a cell's impulse that is firing at a faster rate. The plateau phase lasts about 175 milliseconds, preventing tetany. This leads to an absolute refractory period lasting 200 milliseconds and a relative refractile period of 250 milliseconds, which is enough for heart contraction to occur before the muscle cell is triggered again.

So, the SA node prefers to beat at a rate of 80-100 beats per minute, while those components further down on the electrical system will have rhythmicity at a slower rate. The AV node generates an impulse of 40-60 beats per minute. If this were blocked, the bundle of His would fire at 30-40 beats per minute and, if this were blocked, the bundle branches would beat at 20-30 beats per minute. The Purkinje fibers fire at 15-20 beats per minute if everything else was blocked from conducting. Trained athletes will have a heart rate of about 50-60 beats per minute with the exception of very highly-trained athletes.

ELECTROCARDIOGRAM

An electrocardiogram or ECG measures the electrical activity of the heart. It involves placing sensors or "leads" that measure electrical activity on the limbs of the body and across the anterior chest wall in a specific way that records electrical activity. It is an important tool used in cardiology to assess the health of the heart.

The ECG will determine the heart rate and has a specific waveform that will detect the particulars of cardiac activity. Figure 11 shows an ECG tracing:



The main things seen in the ECG include the P wave, the QRS complex, and the T wave. The U wave is much less likely seen and represents repolarization of the Purkinje fibers. The P wave represents the depolarization of the atria of the heart, while the QRS complex depolarization of the ventricles, which is a stronger signal because of the relative size of this part of the heart. The repolarization of the atria is buried beneath this signal. The T wave represents the repolarization of the ventricles.

Cardiac Muscle Metabolism

Under normal circumstances, the cardiac muscle fibers are entirely aerobic with oxygen necessary for its functioning. For this, a great deal of myoglobin in the heart is necessary for rapid availability of the oxygen molecule during peak performance. Both fatty acids and glucose from the circulation are taken up by the mitochondria and used for ATP energy. There is glycogen and fatty acid droplets in the sarcoplasm for additional nutrients when needed.

Cardiac Cycle

The time period that starts with the atrial contraction and ends with ventricular relaxation is known as the cardiac cycle. The contraction phase, when the heart pumps blood into the circulation, is called systole, while the relaxation and filling phase is called diastole. Both the atria and ventricles undergo systole and diastole; it is crucial to have these components be carefully coordinated to have efficient pumping of blood.

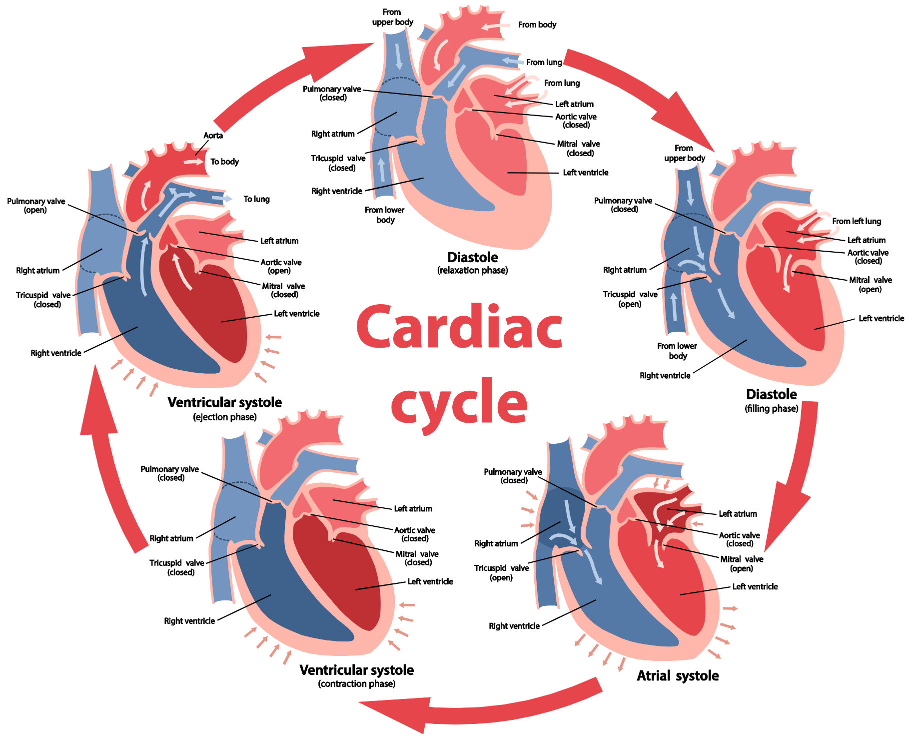
It is important to know that all fluids, including blood, will follow a pressure gradient. It will move from an area of high pressure to an area of low pressure. Relaxation of the heart allows blood to flow from the veins outside of the heart, to the atria, and into the ventricles. The contraction of the atria forces the blood into the ventricles, where the pressure increases there. The force of ventricular systole will force the blood from an area of high pressure in the ventricles to an area of lower pressure in the aorta and pulmonary arteries.

At the relative “beginning” of the cardiac cycle, both atria and ventricles are completely relaxed in diastole. Blood flows into the right atrium from the inferior and superior vena cava, while the left atrium fills from the pulmonary veins. The tricuspid and mitral valves are open to allow blood to flow into the ventricles as well. About 70-80 percent of ventricular filling happens via this method. The pulmonic and aortic valves are closed so blood does not back into the ventricles.

Contraction of the atria follows depolarization, which results in 20-30 percent of filling of the ventricles—referred to as the atrial kick. Atrial systole lasts about 100 milliseconds and ends just before ventricular systole. Ventricular systole happens when the QRS complex is seen on the ECG. This lasts about 270 milliseconds. At the end of atrial systole (but before there is atrial contraction), the ventricles will contain 130 milliliters of blood. This is called the preload or end-diastolic volume.

At the beginning of ventricular systole, the mitral and tricuspid valves close; blood does not flow into the atrial chambers. The pressure isn't high enough to open the aortic and pulmonic valve, leading to isovolumetric contraction of the ventricles. This means the volume in the ventricles does not change. Ultimately, the valves open and ventricular ejection occurs. Both ventricles will pump the same amount of blood, about 70-80 milliliters. The remaining 50-60 milliliters is called the end systolic volume.

Ventricular diastole or the relaxation phase follows the repolarization of the ventricles or the T wave. The total length of this phase is 430 milliseconds. The blood will flow back into the heart, closing the aortic and pulmonic valves. After this, there is the isovolumetric ventricular relaxation phase, in which the pressure decreases but the volume does not change. Ultimately, the tricuspid and mitral valves close and blood flows into the ventricle, completing the cardiac cycle. Figure 12 shows the cardiac cycle:



This leads to the important topic of cardiac output. The cardiac output is the amount of blood pumped per ventricle in one minute. This is calculated by multiplying the stroke volume per beat by the heart rate. The stroke volume must be measure with an echocardiogram, in which it is measured by taking the end diastolic volume minus the end systolic volume. The average stroke volume is 70 milliliters and the average heart rate is 75 beats per minute, leading to a cardiac output of 5.25 liters per minute with a range of four to eight liters per minute from each ventricle separately.

Things like autonomic innervation, hormones, fitness level, and age will affect the heart rate. Things like heart size, fitness levels, gender, contractility, duration of contraction, preload, and afterload will affect the stroke volume. Together these affect the cardiac output. The ejection fraction is another important calculation, which is the percentage of blood ejected per beat from the ventricle. The normal ejection fraction is 55 to 70 percent.

Heart rate can increase to 150 beats per minute in a healthy person during exercise with the stroke volume increased to 130 milliliters per beat. This will increase the cardiac output to four to five times the resting rate. Athletes at peak performance can have resting cardiac outputs of up to eight times the resting rate. The difference between the maximum and resting heart rate is called the cardiac reserve, which measures the residual capacity of the heart to pump blood.

Heart rate varies considerably with age, fitness levels, and exercise. The maximum, as identified by the rate the AV node can handle is about 220 beats per minute. As one ages, this maximum level decreases so the maximum is about 220 minus one's age. This means that a 60-year-old person can exercise to a maximum of 160 beats per minute.

If the rate becomes too high, the amount of blood that can fill the ventricles will decrease so that the cardiac output decreases. This is because the ventricles do not have the chance to fill completely during diastole. Heart rates above 160 in the healthy person will actually decrease the cardiac output. Because of this, the target heart rate in the exercising person is between 120 and 160 beats per minute so as to get the maximum benefit from the exercising process. Remember, though, that it will depend on age, which will be discussed in another chapter.

There are cardiovascular centers that control the heart rate, located in the medulla oblongata of the brain. There are cardioaccelerator and cardioinhibitory nerves that will increase and decrease the heart rate, respectively. Both centers will act on the heart at rest, leading to what's referred to as autonomic tone—the resting tone of the heart. The vagal or parasympathetic stimulation is greater than the sympathetic tone. If there was no parasympathetic tone, the sinoatrial or SA node would lead to a sinus rhythm of 100 beats per minute.

There is an autonomic cardiac plexus located at the base of the heart, with sympathetic and parasympathetic fibers leading to the heart. There are more sympathetic than parasympathetic nerves innervating the heart. Sympathetic fibers will release the neurotransmitter norepinephrine to the atrioventricular or AV nodes, increasing the heart rate. The sympathetic input will increase the heart rate, while the parasympathetic input will decrease the heart rate.

There are a couple of cardiac reflexes that are caused by input of receptors that influence the heart rate. Increased physical activity triggers proprioceptor in the body that increase the heart rate, as is the case with physical activity. These receptors are located in the muscles, tendons, and joint capsules.

There are stretch or baroreceptors in the aortic sinus, venae cava, pulmonary vessels, and the carotid arteries. When these receptors are triggered by blood pressure, physical activity, or the relative distribution of blood, there is a baroreceptor reflex in the heart, decreasing heart rate.

The atrial reflex or Bainbridge reflex is associated with the rate of blood flow in the atria. If they sense high blood pressure in the atria, the heart rate will increase by stimulating sympathetic heart input. The reverse is true with low blood pressure sensation in the atria.

There are chemoreceptors that react to carbon dioxide and acidity in the blood as well as falling oxygen levels, which give feedback through the cardiovascular centers to increase or decrease the heart rate as needed to maintain homeostasis or "sameness" in the system. The limbic system or emotions will increase the heart rate and meditation will decrease heart rate in accordance with the person's emotional state.

There are factors that will affect the overall cardiac output by affecting the stroke volume of the heart. These include thyroid hormones, potassium and calcium levels, sodium levels, body temperature, and stimulants like caffeine and nicotine. Thyroid hormones will increase both the heart rate and contractility of the heart. Caffeine and nicotine will increase the heart rate as well. Low oxygen levels will decrease heart rate by influencing the metabolism of the heart. Acidosis or low blood pH will affect the heart rate in complex ways. The higher the body temperature, the higher the heart rate.

Cardiorespiratory Response to Exercise

As muscle start to exercise, the small arterioles in the muscle will dilate in order to provide more blood flow to the exercising muscles. This would naturally decrease peripheral resistance and will lower blood pressure. But this does not happen in reality. This is because the heart adjusts to this phenomenon by increasing the blood pressure and force of contractility. The increase in carbon dioxide, increased acidity, and increased potassium concentration of the tissues will cause dilation of these small vessels, increasing blood flow to as high as 20 times the baseline level.

The higher centers of the brain that begin muscle contraction will have anticipatory effects on the cardiovascular system, increasing the cardiac output and the dilation of the muscle arterioles at the same time so that the blood pressure remains stable in the beginning of exercise. There is sympathetic input to the heart that increases the heart rate and the stroke volume at the same time. Muscles pump blood back to the heart, increasing the preload pressure to the heart so it can pump blood more effectively.

While the skeletal muscle being acted on will have dilation of their muscle arterioles, other arterioles in the body will constrict. These include those in the skin, gut, and inactive muscles. The gut will respond by digesting food to a lesser degree during exercise.

In long-term, endurance exercising, however, the activities of absorption and digestion will ultimately begin again. In the same way, it is necessary to have the skin give off heat during exercise so that the arterioles will dilate at some point in order to facilitate this process. With each of these factors, the mean arterial pressure will ideally remain constant during exercise.

The goal of the cardiovascular system during aerobic exercise is to meet the increased oxygen need to the muscles. The body will sense the need for increased oxygen during exercise is to increase the heart rate and stroke volume. It can take up to four minutes of exercise to increase metabolism in order to meet these oxygen demands. In the meantime, anaerobic systems will allow the energy demand to be met.

At some point, the aerobic metabolism takes over to meet the demand for energy in the presence of oxygen. Before this, however, there will be an oxygen debt, resulting in shortness of breath in the beginning of exercise. After exercise, the cardiovascular system will normalize and the oxygen debt will be made up. The ongoing elevation of respirations, blood pressure, and cardiac output will slowly decrease in order to remove the exercise byproducts like lactic acid that have built up during the exercise process.

KEY TAKEAWAYS

- The base of the heart is where the blood vessels exit and the apex is the most inferior portion of the heart.
- There are four chambers to the heart—two filling and two pumping chambers.
- The heart's blood supply comes from coronary arteries that do not have a great deal of overlap.
- The two phases of the cardiac cycle are the diastolic or relaxation phase and the systolic or contraction phase.
- The electrical activity of the heart can be determined by the electrocardiogram.
- The cardiac output is the heart rate multiplied by the stroke volume per ventricle.
- Exercise will increase both the stroke volume and the heart rate, which will increase the cardiac output. The blood pressure will remain roughly the same.

QUIZ

1. Which part of the heart has its major vessels exiting from?

    a. Cardiac notch
    b. Base
    c. Apex
    d. Pericardium

    Answer: b. The base of the heart, which is actually the top of the heart, is where the major vessels exit and enter the heart. The apex is the bottom of the heart, which is narrower and sits at the bottom of the heart. In a sense, the heart is shaped like a pinecone.

2. Which is the part of the left inferior lob of the lung that forms a depression to allow the heart to fit on its left side within the chest cavity?

    a. Cardiac notch
    b. Mediastinum
    c. Pericardial sac
    d. Pericardium

    Answer: a. The cardiac notch is the depression in the left lung that allows the apex of the heart to fit within a space on the left side of the chest cavity.

3. Which is the valve that opens to send blood to the systemic circulation?

    a. Aortic valve
    b. Pulmonic valve
    c. Tricuspid valve
    d. Mitral valve

    Answer: a. The aortic valve opens to send the oxygenated blood to the systemic circulation from the left ventricle.

4. Which septum in the heart is the thickest, containing the electrical pathways important for the functioning of the heart's electrical system?

    a. Atrioventricular septum
    b. Septum primum
    c. Interatrial septum
    d. Interventricular septum

        Answer: d. The interventricular septum is the thick septum between the ventricles that contains necessary electrical pathways for the heart's electrical system.

5. Which is the innermost layer of the pericardium around the heart?

    a. Serous pericardium
    b. Epicardium
    c. Parietal pericardium
    d. Endocardium

        Answer: b. The epicardium is fused with the heart itself, making it the innermost layer of the pericardium. The parietal pericardium is fused with the fibrous pericardium. Together, the epicardium and the parietal pericardium make up the serous pericardium, which is a relatively delicate layer of this pericardial sac.

6. What is the innermost layer of the heart, which is continuous with the innermost layer of blood vessels exiting and entering the heart itself?

    a. Endothelium
    b. Endocardium
    c. Myocardium
    d. Epicardium

        Answer: a. The endothelium or endothelial layer is the innermost lining of the heart that is intimately connected to the blood within the heart and that is contiguous with the innermost layer of the blood vessels exiting and entering the heart. The endothelium is a layer that itself is a part of the endocardium of the heart.

7. What structure of the electrical system of the heart establishes the maximal heart rate in an exercising person of 220 beats per minute?

   a. Atrioventricular node
   b. Sinoatrial node
   c. Bundle of His
   d. Purkinje cells

   Answer: a. The AV node has a maximum ability to pass on a signal of 220 beats per minute without impeding myocardial contraction. The SA node can go faster than this but will be limited by the rate of the SA node.

8. Which aspect of the electrical system of the heart spreads the electrical impulse to the vast majority of the ventricles of this organ?

   a. Atrioventricular node
   b. Sinoatrial node
   c. Bundle of His
   d. Purkinje cells

   Answer: d. The Purkinje cells are those that quickly spread the impulse of the heart from the base of the ventricles and across the muscle cells of the ventricles.

9. What does cardiac muscle use mainly for its nutrient supply?

   a. Myoglobin
   b. Amino acids
   c. Cholesterol
   d. Fatty acids and glucose

   Answer: d. Cardiac muscle is an aerobic muscle, using primarily fatty acids and glucose as the main nutrients metabolized for the creation of ATP.

10. What occurs last in a typical cardiac cycle?

    a. Ventricular diastole
    b. Ventricular systole
    c. Atrial systole
    d. Isovolumetric ventricular systole

Answer: a. Ventricular diastole occurs at the beginning and end of the cardiac cycle. Atrial diastole also occurs at the beginning of the cycle, with atrial systole happening to push the rest of the blood in the atria into the ventricles.

Chapter 3: Respiratory System and Exercise

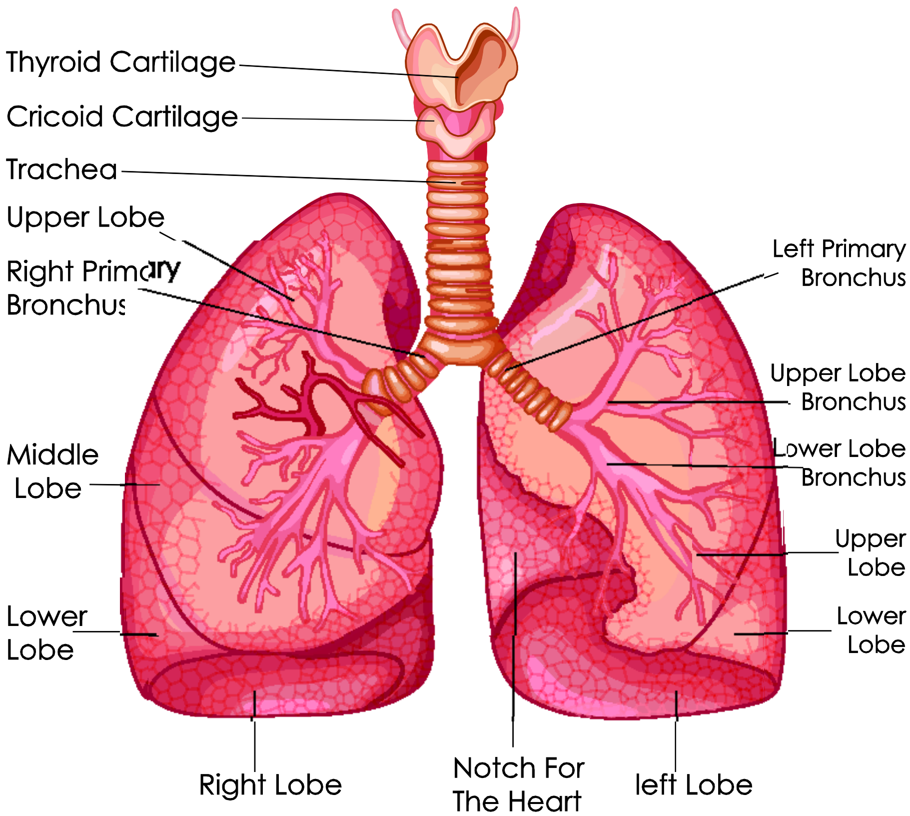
This chapter focuses on the respiratory system, what it involves, how it works, and how it responds to activity. The anatomy of the lungs is covered, including how they take in oxygen and exchange oxygen and carbon dioxide at the level of the alveoli. In addition, the chapter covers the way the two gases are transported in the body and how the reverse exchange happens at the tissue level. The way in which exercise influences the respiratory system is also covered.

Lung Anatomy

There are two major zones in the respiratory system: the conducting and the respiratory zone. The conducting zone involves the nose, nasopharynx, larynx, trachea, and many of the major bronchi that pass air in and out of the lungs but do not participate in actual gas exchange. The respiratory zone is primarily the lungs themselves. There is a large surface area encompassing the gas exchange area of the lungs, which is about 70 square meters. This is the area that is highly permeable to oxygen and carbon dioxide.

The lungs are paired organs that are connected in the middle of the chest cavity by the trachea and the left and right mainstem bronchi. The inferior surface of the lungs is bordered by the diaphragm, which is a muscle that separates the thoracic and abdominal cavity. The diaphragm contracts, allowing for the intake of air into the lungs. Most of the time, particularly at rest, the intake of air through the diaphragm and accessory muscles of breathing is an active process, while expiration is a passive process. Figure 13 shows the anatomy of the lungs:

Lungs Diagram



The right lung tends to be bigger than the left lung, particularly because there is an indentation of the left lung for the heart to fit, called the cardiac notch. The lung's apex is the upper region of the lung, while the base is the bottom of the lung. The costal surface is the part bordering the ribs, while the mediastinal surface faces the midline.

There are five total lung lobes. There are fissures that separate these lobes from each other. There are three lobes in the right lung: superior, inferior, and middle lobes. The left lung has two lobes: the inferior and superior lobes. The lobes are divided into bronchopulmonary segments, each of which receives its air from its own tertiary bronchus, supplied by its own artery. A pulmonary lobule has its own large bronchiole that has many branches.

The major function of the lung tissue is to perform gas exchange, which receives blood from the pulmonary circulation. This is separate from the systemic circulation discussed in chapter two. The blood starts as deoxygenated blood from the pulmonary arteries and contains red blood cells that take up oxygen in the lungs. The pulmonary arteries branch into multiple smaller arteries and arterioles until they become pulmonary capillaries, which is where gas exchange occurs. Arteries and veins exit the lungs through the hilum in the medial aspect of each lung.

The parasympathetic and sympathetic nervous systems both contribute to the innervation of the lungs. The parasympathetic nervous system accounts for bronchoconstriction or narrowing of the bronchial tree, while the sympathetic nervous system accounts for bronchodilation or dilation of the bronchial tree. There are reflexes, like coughing and the regulation of gas levels, that are also under autonomic control. There are sensory nerves that have parasympathetic and sympathetic influences.

The lung pleura is the lining of the lungs. The pleura is an enclosed space that is, in essence, a potential space consisting of a visceral pleura adherent to the lungs and a parietal pleura adherent to the chest wall, diaphragm, and mediastinum. These two layers connect at the hilum. There are just a few milliliters of fluid within the pleural space. The purpose of this fluid is to lubricate the lining of the lungs as they expand and contract with inspiration and expiration.

Pulmonary Ventilation

The act of breathing is called pulmonary ventilation. This is the movement of air into and out of the lungs themselves. The three things that factor into pulmonary ventilation is the atmospheric pressure (the pressure in the surroundings), the pressure in the alveoli (alveolar pressure), and the pressure within the pleural cavity (intrapleural pressure).

Breathing cannot happen without differences in pressure between the atmosphere and the lungs. In any gas, a force will be created by the movement of the gas molecules within a prescribed volume. The same amount of gas in a large volume will have a lesser pressure than it will in a small volume. According to Boyle’s law, if the temperature is held constant, there is a difference in pressure that is completely defined by the volume it occupies. The pressure in a two-liter container is half the pressure of the same volume of gas in a one-liter container.

The lungs make use of this pressure-volume law. The atmospheric pressure is identified as one atmosphere at sea level, which is equal to 760 millimeters mercury. All other pressure values when understanding breathing are in relation to the atmospheric pressure so that, for the purposes of breathing, any pressure that is equal to the atmospheric pressure will be set as zero.

The intra-alveolar pressure is the changing pressure of the gases within the alveoli. In reality, the interpulmonary pressure of the alveoli will always equal the atmospheric pressure. The intrapleural pressure is the pressure of air within the pleural cavity, between the visceral and parietal pressure. It also changes with the phases of breathing but will also be lower than or negative in relation to the intra-alveolar pressure and the atmospheric pressure. While it fluctuates, it is approximately negative four millimeters of mercury. It needs to be low in order to keep the lungs from deflating.

There are competing forces within the thoracic cavity that forms a negative intrapleural pressure. One of these is the elasticity of the lungs that pull the lungs away from the chest wall. There is the surface tension of alveolar fluid to consider, that acts to keep the lungs attached to the wall. Too much or too little fluid will impede this action. This outward pull of the alveolar fluid surface tension is greater than the elasticity of the lungs and creates the negative four millimeters of mercury needed to maintain the intrapleural pressure.

What determines the size of the lungs is the transpulmonary pressure. This is the difference between the intrapleural and intra-alveolar pressure. High transpulmonary pressure translates into a larger lung size.

The lungs themselves are relatively passive during the breathing process. It takes contraction of the diaphragm as the main factor in causing inspiration, although the intercostal muscles participate in inspiration and forced expiration to a lesser degree. These cause pressure changes within the lungs that result in the inspiration and expiration of air. Air can rush into the lungs or exit the lungs as a way of equalizing the pressures between that which is in the lungs and that which is in the atmosphere.

Force is necessary to engage in respirations. There is some resistance to the flow of air that will slow its motion. The size of the airway most affects the resistance, with smaller bronchial tubes causing greater resistance to flow. There is also surface tension within the alveoli caused by water in the lining of the alveoli. Surface tension in general tends to block the expansion of the alveoli; however, there is pulmonary surfactant secreted by alveolar cells that mixes with the water, acting like a detergent that aids in the expansion of the alveoli and prevents complete collapse of the alveoli during expiration.

The compliance of the thoracic wall is the ability of the chest wall to stretch and expand while under pressure. This has a positive effect on the effort expended in the process of breathing. In order for there to be adequate inspiration, there must be expansion of the thoracic cavity. If the thoracic wall tissues are not compliant, it will be difficult to expand the thorax in order to increase the size of the lungs.

Air—and any gas—will flow down a pressure gradient from an area of high to an area of low pressure. The difference in pressure caused by the increase in lung size is what draws air into the lungs in order to equalize the pressure. When the lungs relax and the size of the lungs decreases, the air flows out of the lungs. Again, this is in order to equalize the pressure between the alveoli and the outside air.

The two steps involved in a respiratory cycle are inspiration and expiration. When we inspire, we draw in air. When we expire, air leaves the lungs. The two main muscle groups, as mentioned, are the diaphragm and the intercostal muscles between the ribs. There are additional chest and neck muscles that can be recruited in forced inspiration and expiration. The diaphragm is dome-shaped and is drawn downward when it contracts. The intercostal muscles contract, drawing the ribs upward, causing the expansion of the rib cage, increasing the volume of the thoracic cavity.

Because of adhesive forces of the pleural fluid, when the thoracic cavity expands, the lungs will also stretch and expand. This volume increase leads to a decrease in intra-alveolar pressure, creating a lower pressure than exists in the atmospheric pressure. This pressure gradient tends to drive air into the lungs. Expiration is itself passive, meaning that little energy is required in order to push air out of the lungs. It is the elasticity of lung tissue that causes the lung to recoil rather than any muscle contraction.

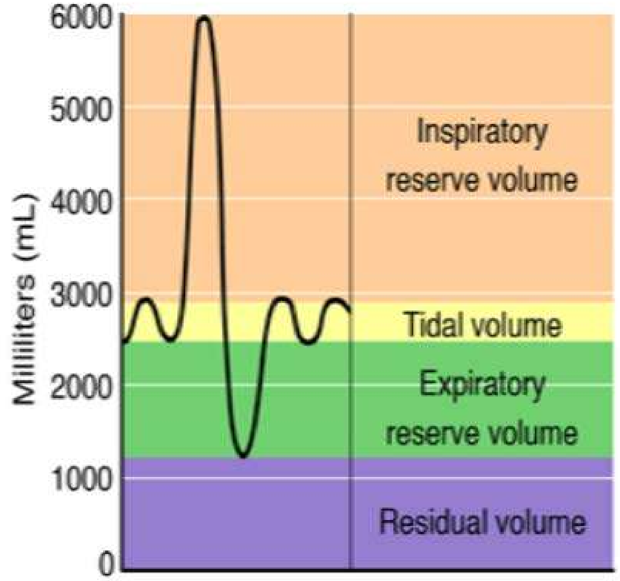
There are three types of breathing in the average person. Quiet breathing or “eupnea” is a mode of breathing that happens at rest. The diaphragm contracts and the intercostal muscles contract but this does not require the cognitive thought of the individual. Deep breathing involves deep diaphragmatic contraction, while costal breathing requires contraction of the intercostal muscles.

In forced breathing or hyperpnea, there is breathing that can occur during exercise or in those actions that require active breathing, such as singing and loud speaking. This type of breathing requires contraction during inspiration and expiration. The muscles of the neck, such as the scalene muscles, will help to lift the thoracic wall in order to increase lung volume. Accessory muscles of the abdomen, including the abdominal oblique muscles, will push the diaphragm further into the thorax so that more air can be pushed out. There are internal intercostal muscles that aid in compressing the rib cage, reducing the volume of the thoracic cavity in the expiration process.

Respiratory Capacities and Respiratory Volumes

Respiratory volume is the term used for the different volumes of air associated with the lungs at a given point in the respiratory cycle. There are four volumes that are important to understand. The tidal volume is the amount of air entering the lungs during quiet breathing. This is about 500 milliliters. The expiratory reserve volume is the amount that can be forcefully exhaled beyond the normal tidal volume, which can be as much as 1200 milliliters. The inspiratory reserve volume is the amount of air that can be produced when breathing in past the tidal inspiration. The residual volume is the air left in the lungs after a full exhalation. This is the volume that prevents alveolar collapse. Figure 14 shows these lung volumes:

Lung Volumes



The total lung capacity or TLC is the sum of all of the lung volumes. This is the total amount of air that can be held after a forceful inhalation. This is about 4200 milliliters for women and about 6000 milliliters for men. The vital capacity is the amount of air a person can move into or out of the lungs and does not include the residual volume. The functional residual capacity is the amount of air that remains in the lung after a normal expiration—the sum of the residual volume and the expiratory reserve volume.

There is also an anatomical dead space, which represents air that never reaches the alveoli so never gets exchanged. This is added to the alveolar dead space (air within the alveoli that doesn't get exchanged) to make the total dead space, which is all the air that is not used in the air exchange process.

CONTROL OF VENTILATION

Breathing tends to occur without thinking, even though it can be controlled. The respiratory rate is defined as the number of breaths per minute. Respiratory rates are measured because they can be important indicators of disease; certain diseases will increase or decrease the respiratory rate. Similar to the cardiovascular centers in the medulla oblongata, there are centers in this part of the brain that control the respiratory rate based on the carbon dioxide levels, oxygen levels, and pH of the blood.

The normal respiratory rate will be highest at birth and will decrease over time. An infant will have a respiratory rate of between 30 and 60 breaths per minute, with a child at age 10 years having a respiratory rate of between 18 and 30 breaths per minute. Adults and adolescents will breathe at a rate of 12 to 18 breaths per minute at rest.

There are many reflexes and control centers that have control over the respirations. The medullary centers (in the medulla) set the basic breathing rhythm. There is a ventral and dorsal respiratory group in the medulla that integrate information from the periphery of the body and a pontine respiratory group that influence the medulla oblongata. The dorsal respiratory group sets the baseline respiratory rate, while the ventral respiratory group is responsible for forced breathing.

There is a second respiratory center in the pons, referred to as the pontine respiratory group. There are two centers in this group. The apneustic center controls the depth of inspiration and is helpful in deep breathing. The pneumotaxic center inhibits the dorsal respiratory group, controlling the respiratory rate by allowing for relaxation after breathing in.

There are sensory receptors (chemoreceptors) that monitor the pH, oxygen level, and CO2 level in the aorta and carotid arteries. The hypothalamus controls the breathing rate through the recognition of the body temperature and emotional state. The cortex in the brain exerts voluntary control over the breath rate, while proprioceptors in the joints and muscles are triggered to increase the breath rate with exercise. In the lungs, there are pulmonary irritant reflexes that protect the lungs from foreign substances and an inflation reflex that protects the lungs from over-inflation.

The concentration of carbon dioxide plays a more significant role in the production of respiration rather than the oxygen concentration. Carbon dioxide is the waste product of metabolism and, when it builds up, it stimulates breathing. High carbon dioxide levels contribute to a reduction in blood pH (which is low in the presence of acidity). These things can be detected directly by sensors in the brain, contributing to the breathing process. High CO2 levels mean a need for increased rate and depth of breathing. Low CO2 levels will decrease the rate and depth of breathing.

In the same way, lactic acid buildup during exercise will lower the pH and will cause an increase in the need to breathe more rapidly to correct the low pH level. This is partly why breathing rate remains elevated after strenuous exercise. The sensors for pH are located in the aortic arch and carotid arteries. Changing the breath rate will blow off or retain CO2, changing the pH so it will normalize.

It takes very low oxygen levels to affect the breathing rate. The peripheral chemoreceptors can only sense oxygen that is not bound with hemoglobin—just the dissolved oxygen in the bloodstream. Because hemoglobin will release more oxygen during low oxygenation periods, it takes a very low oxygen level to trigger this chemoreceptor type.

Gas Exchange in the Lungs

The whole purpose of the respiratory system is to exchange gases (oxygen and carbon dioxide) in the alveoli of the lungs. All of this occurs at what's called the respiratory membrane, which is where the alveolar and capillary walls meet and fuse together. Oxygen from the air passes into the bloodstream, while carbon dioxide from the blood exits the system to be exhaled by the lungs themselves.

We've already discussed Boyle's law but there are other laws that apply to gas exchange in the lungs. Another law that applies here is that related to the partial pressure of a gas. Air is not just oxygen but is a mixture of nitrogen (which has the highest concentration), oxygen, carbon dioxide, and other gases. The total pressure of a gas is the sum of the pressures (called partial pressures) of the gases separately. This fact is known as Dalton's law of partial pressures.

Gases, even those in a mixture, will go from an area where its partial pressure is the highest to where its partial pressure is the lowest. The greater the difference in the partial pressure, the more rapid is the movement of the gas from one area to another.

Another gas law that applies to human respiration is Henry's law. This law applies to the behavior of a gas when it comes in contact with a liquid, such as that seen with blood. According to Henry's law, the concentration of a gas in liquid is proportional to its solubility in the liquid and the partial pressure of the gas. The higher the partial pressure of the gas, the greater number of particles that will be able to dissolve in the liquid. Some gases, however, are not as soluble in a liquid when compared to others. Nitrogen has a high partial pressure in air but a low solubility in blood so it isn't present in high concentrations of blood.

Gas exchange in the lungs depends on ventilation and perfusion. Ventilation involves air moving in and out of the lungs. Basically, the alveoli need to have air available for gas exchange to occur. Perfusion is also necessary, which means that the blood must come in contact with alveoli for gas exchange to occur. Anything that impairs this matchup will impair respiration.

The partial pressure of oxygen in the alveoli is 104 millimeters of mercury, while the partial pressure of high-oxygen pulmonary venous blood is 100 millimeters of mercury. This means that there is a very good exchange of oxygen in the lungs while ventilation is good. The body will adjust to mismatches in ventilation and perfusion by redirecting blood to the highly ventilated alveoli. There are local factors that constrict some vessels and dilate other vessels so that ventilation and perfusion can be better matched. High oxygen levels in the alveoli will increase the blood flow to the area.

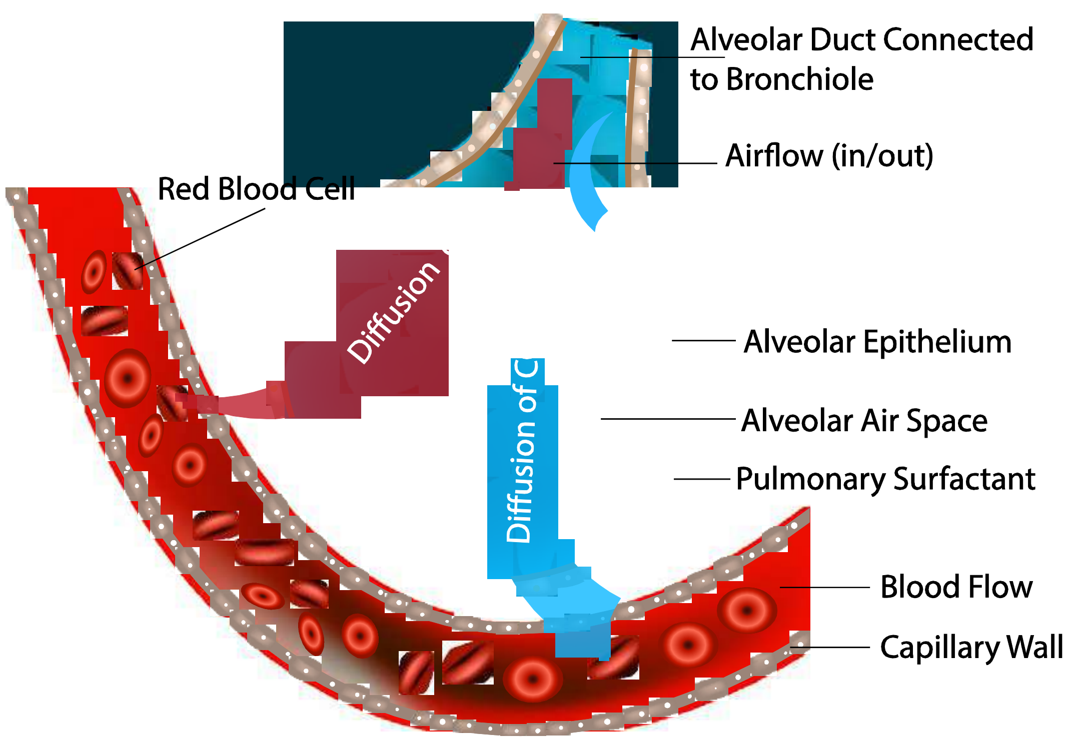
Ventilation is also regulated through local mechanisms. The areas with a high partial pressure of carbon dioxide will have dilation of the bronchial tree in order to maximize ventilation. The same can be said of decreased oxygen levels in the blood, which will also increase bronchial dilation so that $CO2$ can be exhaled at a greater rate. The goal of these changes is to maximize the ventilation-perfusion match.

Gas exchange actually happens at two places in the body. These are at the level of the lungs and the tissues. In the lungs (external respiration), oxygen is taken up and carbon dioxide is expelled out of the body; in the tissues (internal respiration), the oxygen goes from the bloodstream into the tissues, while carbon dioxide leaves the tissues and enters the bloodstream.

The exchange of gases is due to simple diffusion across the cell membranes. It does not require energy of any kind and gases will follow pressure gradients. The respiratory membrane is quite thin and gases will readily diffuse across this cellular membrane.

Pulmonary vasculature branches into small capillary branches that actually interact with and surround the alveoli for gas exchange. Most of the oxygen will be picked up by hemoglobin rather than being dissolved in the bloodstream itself. Hemoglobin is a red protein when oxygen is attached to it, giving the blood its red appearance. Carbon dioxide will also be returned on hemoglobin; however, it is more soluble in blood than is oxygen (or even nitrogen). Figure 15 shows gas exchange in the alveoli:

GAS EXCHANGE WITHIN ALVEOLI



Again, the solubility of oxygen is not high. There is a big difference, though, between the partial pressure of oxygen in the alveoli versus the blood, amounting to 64 millimeters of mercury. As mentioned, the partial pressure of oxygen in the alveoli is about 104 millimeters of mercury, while that of blood capillaries is 40 millimeters of mercury. This creates a big pressure gradient allowing for rapid flow across the respiratory membrane.

The partial pressure of carbon dioxide is also the driving force for its transport out of the blood. The partial difference is only about five millimeters of mercury or about 45 millimeters of mercury in the bloodstream versus 40 millimeters of mercury in the alveoli. The big difference, though, is in the solubility of carbon dioxide in both of these areas (it is 20 times greater than that of oxygen). This makes the flow of this gas as great as it is with oxygen.

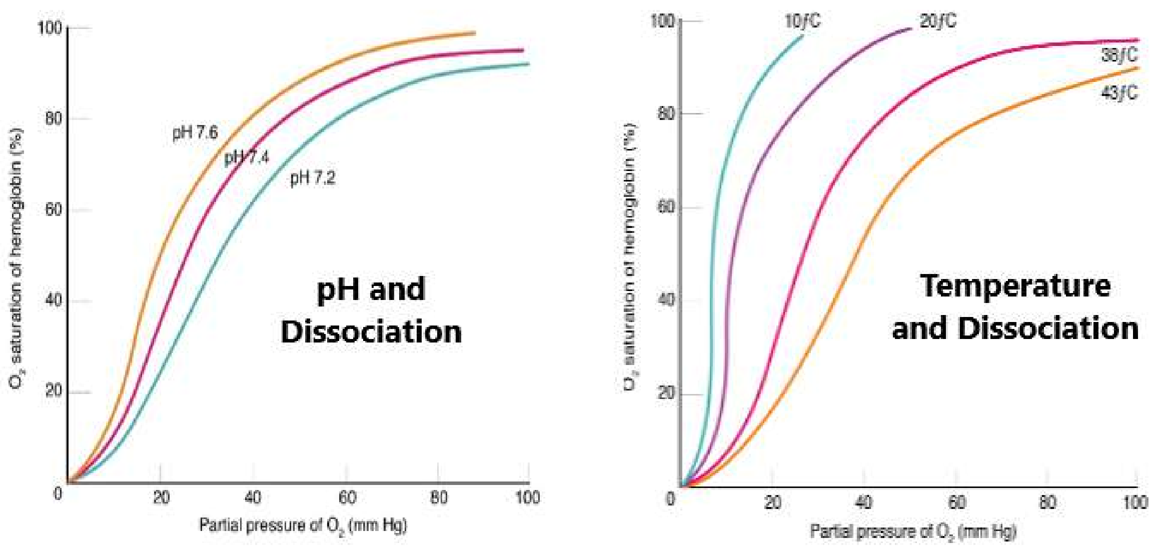
Internal respiration is gas exchange that happens in the body at the tissue level. It also involves simple diffusion secondary to a partial pressure gradient. The partial pressure gradient for oxygen is about 60 millimeters of mercury, while the partial pressure gradient for carbon dioxide promotes CO2 to go from the tissues to the blood. The hemoglobin is darker in color because it is deoxygenated.

Oxygen Transport

Gases need to be transported from the lungs to the tissues and back again. As mentioned, carbon dioxide is more soluble in blood than oxygen but, because of hemoglobin, their transport can be easily accomplished through the human circulatory system. Only about 1.5 percent of oxygen is dissolved in blood. The rest is transported in red blood cells through hemoglobin—a metalloprotein. There are four heme subunits per hemoglobin molecule so that four oxygens can be carried by one hemoglobin protein. This leads to a molecule called oxyhemoglobin. The actual hemoglobin molecule saturation is 95 to 99 percent.

The partial pressure of oxygen and its attachment to hemoglobin is based on the oxygen-hemoglobin dissociation curve. The more oxygen molecules are around, the greater is the affinity for oxygen by hemoglobin. Figure 16 shows the oxygen-hemoglobin dissociation curve as it relates to temperature and pH:

Oxygen-Hemoglobin Dissociation



These graphs have practical applications. Some tissues have a higher metabolic rate than others so they have more metabolic waste products and a low pH from these waste products. It is in these tissues that oxygen will more readily be given off by hemoglobin. At higher temperatures as well, oxygen will be given off to the tissues to a greater degree so muscles generating heat will have more oxygen available to them. Androgens, growth hormone, epinephrine, and thyroid hormones will promote the dissociation of oxygen and hemoglobin by synthesizing BPG (2,3-bisphosphogylcerate) that promotes this dissociation.

This low pH of blood and the increased dissociation of oxygen and hemoglobin is referred to as the Bohr effect. High pH will inhibit oxygen dissociation. Carbon dioxide will lower the pH and will allow for more availability of oxygen for tissues producing a great deal of carbon dioxide through metabolism. This is especially helpful in exercising muscle tissue, which also produces lactic acid as part of metabolism. This lactic acid will also lower the pH and increase oxygen availability.

Carbon dioxide is transported three ways in the blood. The first is through the solubility of carbon dioxide in blood plasma. The second is the transport via bicarbonate, which is the base form of carbon dioxide (or what carbon dioxide looks like under basic conditions rather than acidic conditions). The third is through the binding of carbon dioxide to hemoglobin.

About 7-10 percent of carbon dioxide is dissolved in blood unchanged. Most, 70 percent, gets diffused as bicarbonate ions. Carbonic anhydrase is the enzyme that causes carbon dioxide and water to make carbonic acid, which gets dissociated into bicarbonate and hydrogen ions. About 20 percent of carbon dioxide is bound to hemoglobin and goes to the lungs. This is called carbaminohemoglobin.

According to the Haldane effect, there is a relationship between the partial pressure of oxygen and the affinity of hemoglobin for carbon dioxide. The lower the partial pressure of oxygen, the greater is the affinity of hemoglobin for CO2. This means that the affinity will be higher at the tissues when oxygen is exchanged for CO2 at the tissue level.

Exercise and the Respiratory System

There is a great deal of stress placed on the body during exercise, with a need for about 8-10 times more oxygen during exercise than during rest. The heart and lungs go into action in order to increase the heart rate and breath rate to accommodate exercise. There are both short-term and long-term effects of exercise on the respiratory system.

The breath rate will increase with exercise from 12 to 18 breaths per minute to 40 to 60 breaths per minute during a workout. The tidal volume or amount of air inhaled and exhaled per breath increases during and after exercise. This increases the rate of exchange of oxygen and carbon dioxide.

Over the long term, there will be an increase in the strength of the respiratory muscles, including the diaphragm and intercostal muscles. The chest cavity enlarges and the respiratory volume or lung capacity is greater. The number of capillaries around the alveoli increases so that gas exchange is more efficient. There is an elevation in the oxygen levels in the body with exercise, which enhances other aspects of body functioning.

KEY TAKEAWAYS

- The lungs have five lobes and participate in gas exchange as its primary role.
- The diaphragm and intercostal muscles contract in order to draw air into the lungs. Expiration is usually passive.
- There are centers in the brain that control the rate and depth of respirations, with input from many receptors in the periphery.
- Gases will diffuse from areas of high concentration to areas of low concentration.
- Different gases have different solubilities in blood, affecting the ability to get into the circulation.
- Hemoglobin plays a role in getting oxygen and carbon dioxide transported in the bloodstream.
- There are several gas laws and effects that control the movement of gases in the alveoli and bloodstream as well as on the dissociation of oxygen from hemoglobin.
- Exercise has long-term and short-term effects on the respiratory system.

QUIZ

1. The part of the lung that faces the midline of the lungs is called what?

    a. Costal surface
    b. Base
    c. Apex
    d. Mediastinal surface

    Answer: d. The mediastinal surface is the part of the lungs that faces the midline or the mediastinum of the thoracic cavity.

2. How many lobes are there in the lungs in total?

    a. 2
    b. 5
    c. 7
    d. 12

    Answer: b. Five lobes are in the two lungs. There are three lobes to the right lung (inferior, middle, and superior) and two lobes to the left lung (inferior and superior). These are divided into multiple lobules.

3. What helps prevent the collapse of the alveoli in the lungs during expiration?

    a. Surface tension of water
    b. Pulmonary surfactant
    c. Chest wall compliance
    d. Intercostal muscles

    Answer: b. It is pulmonary surfactant—a detergent-like substance created by the alveolar cells—that allows for the expansion of the alveoli and prevents the full collapse of the alveoli during expiration.

4. What drives the air into and out of the lungs?

    a. The force of atmospheric pressure pushing on the lung tissue.
    b. The force of carbon dioxide in the alveoli
    c. The difference in pressure between the air and the alveoli.
    d. The resistance of the airways

        Answer: c. It is the difference in pressure between the air and the alveoli that is the driving force involved in inspiration and expiration. The resistance of the airways will oppose the flow of air. There is no absolute force involved that drives the airflow but the difference between the pressures themselves.

5. Measured in breaths per minute, what would be considered a normal respiratory rate in an adult?

    a. Six
    b. Nine
    c. Twelve
    d. Twenty

        Answer: c. The respiratory rate in an adult is about twelve to eighteen breaths per minute but will increase with activity.

6. What sensory system responds to exercise in order to increase the respiratory rate?

    a. Proprioceptors
    b. Irritant reflex
    c. Chemoreceptors
    d. Hypothalamus

        Answer: a. Each of these is a factor that acts to alter the respiratory rate; it is proprioceptors in the joints and tendons that increase the respiratory rate in response to exercise.

7. Ventilation to an area of the lungs can be increased by what factor?

    a. Low carbon dioxide levels in the bloodstream.
    b. High carbon dioxide levels in the bloodstream.
    c. Low carbon dioxide levels in the alveoli
    d. High carbon dioxide levels in the alveoli

        Answer: d. Areas with high carbon dioxide levels in the alveoli will increase the bronchial tree dilation so as to increase the ventilation to the lungs in order to draw off the carbon dioxide.

8. What is the method by which oxygen and carbon dioxide cross the respiratory membrane in the lungs?

    a. Active transport
    b. Diffusion
    c. Osmosis
    d. Passive transport

        Answer: b. Diffusion requires no energy nor does it involve channels as is seen with active and passive transport. Osmosis is only applicable to water, while diffusion involves the passage of a substance from a higher concentration to a lower concentration.

9. A fully loaded oxyhemoglobin molecule contains how many oxygen molecules associated with it?

    a. One
    b. Two
    c. Four
    d. Eight

        Answer: c. A fully-loaded oxyhemoglobin molecule contains four oxygen molecules per hemoglobin protein, which is one per heme molecule.

10. What factor does not increase the dissociation of oxygen from hemoglobin?

a. Lower temperatures
b. Lower pH
c. Androgens
d. Thyroid hormone

Answer: a. Each of these will promote the dissociation of oxygen from hemoglobin except that higher temperatures and not lower temperatures will promote this dissociation process.

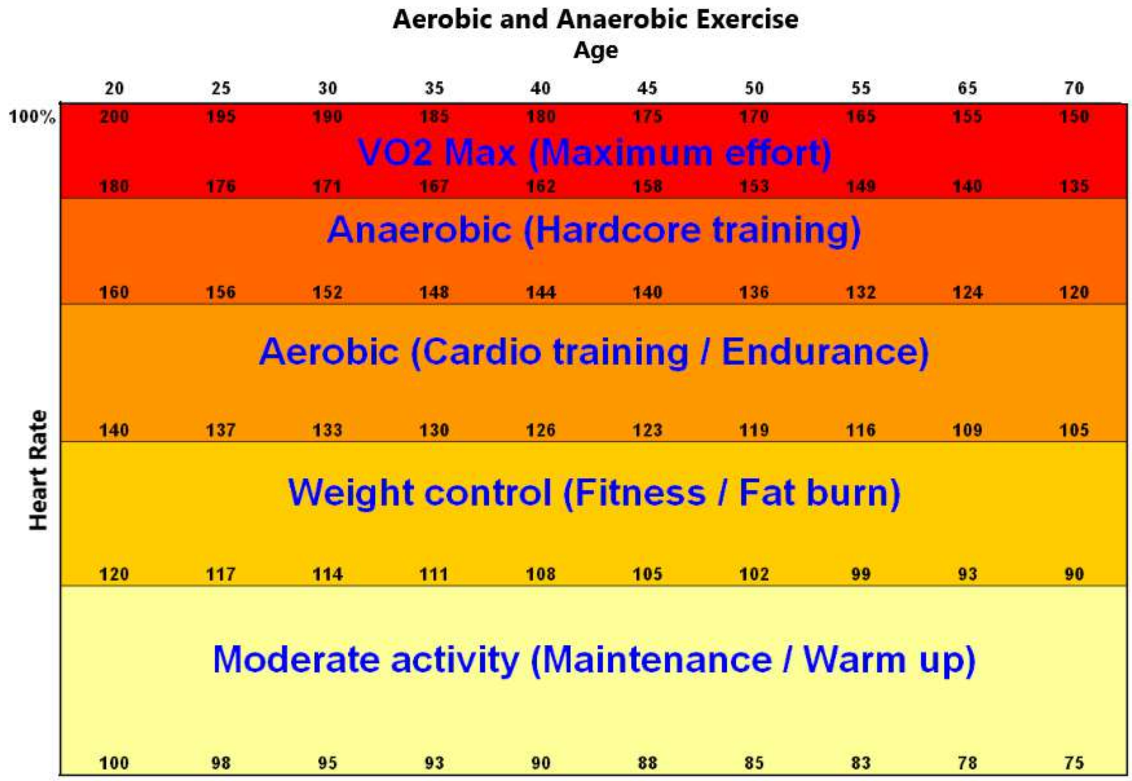
Chapter 4: Anaerobic Exercise and Resistance Training

This chapter discusses the role of anaerobic exercise, which is exercise that does not require oxygen. One of the main types of anaerobic exercise is resistance training, which includes a wide range of activities designed to tone muscles or build muscles. Resistance training or "strength training" is not just for bodybuilders and serves a role in most exercise programs. Types of resistance training and the way the body adapts to resistance training are discussed as part of this chapter.

Anaerobic Exercise

Anaerobic exercise is a type of physical exercise that, by definition, is intense enough to cause lactic acid to build up. It is used in non-endurance sporting events in order to produce increases in speed, strength and power. This type of exercise leads to improved performance in short-duration, high-intensity exercises, lasting up to about two minutes before aerobic metabolism begins to take effect in order to build ATP energy.

We've briefly discussed the role that anaerobic metabolism plays in this type of energy expenditure. The muscles that play the greatest role in this type of exercise are fast twitch muscles. Anaerobic versus aerobic exercise can be partly defined by the target heart rate achieved. As you can see from figure 17, this depends on a person's age. Heart rates in excess of 90 percent of the maximum heart rate for age is considered anaerobic:



As already discussed, there are two types of anaerobic energy mechanisms in place for anaerobic exercise. These include the energy obtained from creatine phosphate and existing stores of ATP, as well as the energy obtained through anaerobic glycolysis, which is the breakdown of glucose to make lactic acid. The creatine phosphate metabolism mechanism is called alactic anaerobic metabolism; glycolysis is referred to as lactic anaerobic metabolism.

High energy phosphates, like ATP, and even creatine phosphate, can only create small amounts of ATP and the ATP can only allow for energy utilization for up to 15 seconds of exercise. Glycolysis can provide ATP in smaller quantities than is obtained through aerobic mechanisms and can only extend the exercise that can be achieved by an additional two minutes.

Traditionally, it has been thought the major byproduct of the glycolytic metabolic pathway—lactic acid—is somehow damaging to muscle tissue. While this is clearly a waste product, it is not through to be detrimental to muscles unless the lactic acid levels are extremely high. In addition, muscle fatigue is more than just a buildup of lactic acid.

It also involves a lack of ATP energy available for the exercising muscles. As it turns out, the muscles can adapt to anaerobic exercise and can improve their ability to utilize anaerobic metabolism.

Anaerobic exercise isn't just weight-lifting. Other types of anaerobic exercise include sprinting (on a bike or by foot), rope jumping, climbing hills, isometric exercises, and any other type of exercise that involves a burst of hard training.

There are benefits of this type of exercise. The most major effect of anaerobic exercise is that it strengthens muscles and enhances muscle mass. It also increases the VO2 max, which is the greatest amount of oxygen the athlete can consume during exercise. This means that it can improve the athlete's cardiorespiratory fitness levels. Over time, this type of training enhances the ability to tolerate the buildup of waste products like lactic acid so they more easily removed from the body.

Anaerobic exercise burns fewer calories than does aerobic exercise overall so it isn't as beneficial for the cardiovascular system than is the case for aerobic exercise. It does benefit the heart and lungs to some degree but it shines in its ability to build muscle mass and strength better than aerobic fitness. An increased muscle mass will aid in weight management because the increased muscle mass will burn more calories than the same amount of fat mass.

As mentioned, training anaerobically will result in the ability to handle lactic acid more efficiently. There will be increased circulation to muscles so that more lactic acid can be drawn off the exercising muscles, which will decrease muscle pain. Buffers against the acidity of lactic acid can be built up that will delay the onset of fatigue during the act of anaerobic exercise. Research has shown that a muscle's buffering capacity can be improved by up to 50 percent, thus allowing more lactic acid to build up without causing excess fatigue.

Unlike aerobic exercise, which involves sustained movement over a long period of time, anaerobic exercise tends to be short-lived and intense, lasting a couple of seconds and up to two minutes. The body in this type of exercise demands more oxygen than can be initially produced so it burns the energy found immediately or over a short period of time. In reality, all forms of exercise are initially anaerobic in the first few minutes, shifting over to aerobic metabolism over time. In the same way, aerobic exercise can become anaerobic when bursts of energy are taken advantage of so as to bring the heart rate up to at least 80 percent of maximum.

The following is a comprehensive list of what is achieved through anaerobic exercise:

- It builds muscle mass by stressing the muscles that will maximize the diameter of the muscle fibers, strengthening the muscles themselves.
- Increases the functionality of fast-twitch muscles, which will increase the speed, strength, and power of the muscles. This accelerates exercise recovery and increases the ability to fight off muscle fatigue.
- Enhances metabolism by having a greater muscle to fat ratio. Muscle burns more calories than fat so more calories get burned and weight loss can be enhanced and maintained. There is also an after-burn, in which calories are continued to be burned after anaerobic exercise.
- It fights depression. Research as shown that individuals who engage in resistance training will have an improvement in depressive symptoms without the use of medications.
- It reduces chronic disease risks, such as diabetes and heart disease. This is partly because it promotes a healthy body weight by the enhancement in muscle mass.
- Strengthens bones by allowing bones to build up during this type of exercise. Bones will strengthen when tension is put upon them so stressing the bones will increase their mass and thickness. This is important in preventing fractures secondary to osteoporosis.
- It reduces the rate of physical aging. Muscle mass reduces with age, which slows metabolism. Research has shown that anaerobic exercise in the elderly will protect against cell death and the aging process by helping to maintain and increase muscle mass.

Types of Anaerobic Exercise

There are many types of anaerobic exercise that are similar to each other in that they involve anaerobic metabolism. Some of these include the following:

- **Weight lifting**—this involves the lifting of heavy objects or using machines that produce muscle contractions against a weight. The goal is to do this repetitively—doing several reps or repetitions over a brief period of time, while resting between repetitions. The athlete will increase the numbers of reps and the weight lifted per rep in order to enhance muscle mass and strength. This is recommended by experts to be done two to three times weekly, even by those who mostly engage in aerobic activity.
- **Sprints**—this can be done as an isolated event or simply "sprinting" or done while engaging in aerobic running. The goal is to take a period of time while running and to run at a maximal effort until fatigued over short periods of time. This can help the athlete increase the pace that can be achieved while running longer distances.
- **Plyometrics**—these include things like one-legged hopping, jump squats, or simply jumping over cones or into and out of a box. These activities will also improve balance and overall muscle power and can be aerobic if done for longer periods of time.
- **Isometrics**—this involves weight training that doesn't allow for a change in length of the muscle, such as pressing the hands together with force or carrying a weight without changing the joint angle. This is a good exercise for arthritics who cannot participate using the full range of motion. The impact of these types of exercises is low so they can be done by just about anyone.
- **High intensity interval training**—this involves swapping aerobic exercise with anaerobic exercise by doing an aerobic activity at slower speeds and then doing intervals of rapid speed and maximal power. Cycling with intermittent bursts of energy is an example of this. It will increase the heart rate into the

anaerobic range and can be done with increased resistance to increase the muscle strength required for brief periods of time.

Resistance Training

Resistance training is any form of exercise that involves the contraction of muscles against an external resistance. The major goals include increasing muscle mass, improving strength and power, toning the muscle, and enhancing endurance to exercise. It can involve using resistance bands, hand weights, the individual's own body weight, or other weight that strengthens the muscles by causing them to contract against a force.

Examples of resistance exercise that many people think of include Olympic-style lifting (lifting weights over one's head), power lifting (bench presses, dead lifts, and squats), and weight lifting of weights for less than six reps at a time. Resistance exercise is not exactly the same thing as "strength training" because the latter involves doing resistance training with the goal of building muscle strength, while resistance exercise can tone muscle without necessarily building strength.

Resistance training is effective because it causes microscopic tears in the muscle tissue, which turn around in the repair process by making themselves stronger and thicker. This is a catabolic or breakdown process accompanied by an anabolic or buildup process. This phenomenon is seen in many biological processes that require breakdown first in order to facilitate growth. Bones also do this, both when injured and when there is the need for bone growth.

There are chemical factors that play into the growth of muscle after a resistance workout. These include the addition of cellular protein, growth hormone, testosterone, insulin-like growth factor, and cellular nutrients. These go to the muscle cells and promote their overall growth and development after working out. The reason why it is necessary to rest for a period of time after a resistance workout is because this period of time is important for the recovery process.

The benefits of resistance training are similar to that of anaerobic exercise but, as you can see, it helps people of all ages. It is recommended as a good exercise choice for individuals at any stage of life with the greatest advantages seen in the elderly. Some advantages include:

- Enhancing muscle tone and strength. Individuals lose five pounds of muscle per decade after the age of thirty. This is especially true of the strength-producing fibers in the body (the anaerobic fibers). This process, which can cause a loss of 25 percent of muscle fibers by age 70, can be reversed or stabilized with resistance training.
- Bone building can occur. The condition of osteoporosis or accelerated bone mineral loss can lead to fractures, particularly in women. Resistance training can reverse this and can help build bone in order to prevent osteoporosis, even in the elderly.
- Resistance training can help lower blood pressure that is in the moderately high range.
- Falls in the elderly can be reduced by better balance and muscle strength. There can be a decrease in fractures due to falls by having better bone strength. Research has also shown that the elderly will walk faster and climb stairs faster. The muscle strength in the elderly can be increased by more than 100 percent—even in the significantly elderly person.
- The metabolic rate can be increased in order to maintain weight to a greater degree.

When starting resistance training, the practice should be progressive in nature with the principles of progressive overload a part of this process. The major muscle groups should be stressed with eight to ten separate exercises performed to cover all muscle groups. About 10 repetitions should be done at once to the point of fatigue. About two to three sessions should be done each week. For older people, exercise with lesser weights at higher repetitions (around 10 to 15 reps per exercise) is preferred.

Progressive overload should be practiced. This involves starting at lower weights and increasing the weights lifted over time in order to progressively strengthen the muscles with the least amount of muscle injury. The goal is to lift weights to a degree that 10 to

12 reps will fatigue the muscle. At the point where the muscle is not fatigued after 10 to 12 reps, the weight should be increased so that the muscle is again fatigued.

Some aspect of free-weight lifting and machine lifting should be done. This is what's done by body builders. There are advantages and disadvantages to both. The advantages and disadvantage of free weights include the following:

- Free weights allow for a variety of exercises to be done for each muscle group.
- They allow for a range of motions that cannot be found when using weight machines, which tend to confine the movements.
- They aid in the enhancement of coordination because of the skill necessary to control the hand weights. This allows for more muscles used to help steady the dumbbells.
- More muscles are recruited when using these hand weights that is seen in machine-work as lifting a hand weight involves both flexor and extensor muscle engagement not always seen when using a machine.
- There is a risk of injury with dumbbells as they can be dropped. Bench pressing can involve dropping a weight, which can be dangerous.
- Dumbbells allow for only so much weight that can be used, while machines offer greater weight increases by adding weight plates to the machine.

The advantages and disadvantages of using weight machines include the following:

- Weight machines are easy to use as they involve switching pins naturally to increase or decrease the weight desired.
- Weight machines are safer than dumbbells as they generally cannot be dropped on the athlete.
- There is less coordination necessary to push or pull on a bar or weight plate compared to using dumbbells.

- The main disadvantages are that these are expensive machines that require a great deal of space with limitations on the number of muscle groups that can be exercised at any given period of time.
- There is the possibility of injury if the machine isn't well-matched to the athlete so that, with those who have limited range of motion, there can be repetitive joint or muscle injuries.

Resistance Bands

Resistance bands are effective and inexpensive for toning muscles of the legs and arms. It involves securing an elastic band around a fixed point (external or internal to the body) and pulling on them in order to activate certain muscle groups. The advantage of using resistance bands is that the power used to pull on the bands can be increased by pulling further away from the fixed point of the band. The closer the athlete is to the point of attachment, the less is the strength required to pull on the band.

Free Weights

Free weights have the advantage of making use of a combination of muscles at one time so the exercise can be more functional. The different choices of free weights include barbells, kettle bells, cardio bells, dumbbells, and body blades. These will use more muscles than can be used with resistance bands or weight machines. Core muscles can be engaged in lifting weights, which can't happen with resistance machines. Improved coordination and proprioception are other advantages to using this type of resistance training.

Resistance Machines

Resistance machines tend to be best for beginners to weight lifting and resistance training because they require less technical ability and postural control. These will allow for muscle strengthening in just one plane of movement at a time so there is the need for several different machines to have the full range of muscle movement. Posture and position are held steady and supported by the machine itself, making this an attractive starting point for individuals who have just begun the strength-training process.

Adaptation to Resistance Training

Adaptation to resistance exercise does not happen in the same way for everyone. In order to have lasting adaptation, there must be the systematic addition of a stimulus of a sufficient size that is followed by recovery with subsequent increase in the stimulus over time.

Over the short-term, resistance training depletes the creatine phosphate and glycogen concentrations. This will decrease the muscle power. There will be an increase in hydrogen ions/acids in the muscle, which decreases the pH and results in the burn felt in the muscles after multiple repetitions.

The main thing that occurs is an increase in muscle size, referred to as hypertrophy. There can be a transient increase in size from fluid accumulation in the intercellular spaces after a single exercise session but this does not last. Added to that is the actual increase in muscle size that occurs with long-term resistance exercise. The muscles in most cases will increase by 20 to 45 percent, requiring in excess of 15 workouts in order to obtain this hypertrophy. There will be a greater increase in fast glycolytic muscle fibers when compared to slow oxidative muscle fibers as the muscles adapt to resistance training.

As you know, the number of muscle fibers (cells) is fixed at birth and does not change. What does change is the thickness of the fibers, which add actin and myosin filaments, more myofibrils, and more sarcoplasm in each cell. There may also be more connective tissue surrounding these muscle fibers.

There will be increases in muscle strength that are not related to increases in the cross-sectional area of the muscle. Instead, it appears to be related to the development of more efficient neural pathways that direct the muscles themselves. This recruitment of motor units is necessary to gain strength in the first two to eight weeks of weight training. Increased activation of synergistic muscle fibers will contribute to the ability of the muscle to create more force against the weight lifted.

The range of increase of strength is variable to the athlete and can be up to 45 percent increased strength. Slow-speed training will aid in the development of gains at slower speeds, while fast-speed training will aid in the development of gains at faster speeds. This means that the gain in strength is velocity-specific.

Another neurological adaptation with resistance training (besides more efficient recruitment) is the decrease in co-contraction of the opposite or antagonist muscles. This co-contraction happens when both the agonist and antagonist muscles fire at the same time, decreasing the power of the agonist muscles. When the antagonist muscles relax to a greater degree, there will be an increase in the power of the agonist muscles.

There is also an increase in the load to the bones, which is created by muscle contractions and other forces against the bones. This results in bone remodeling and an increase in the numbers of protein molecules that are placed in the spaces found between bone cells. The end result is increased mineralization and the addition of calcium phosphate crystals, which cause the bones to increase in density, particularly at the periosteum or outer layer of the bone.

It takes a progressive increase in the load as well as variations in the load parameters to stimulate bone growth. Osteoporosis primarily involves fractures of the axial skeleton, which is the spine and hip area, so this is the area that must take some type of load if resistance training is going to help decrease the risk of fracture. Examples of these types of exercises include squats and lunges, with greater loads recommended over time. Multiple sets are recommended for the stimulation of bone growth.

Resistance training can decrease the percentage of body fat. This will also help in weight loss because it will maximize the energy expenditure during exercise and recovery. This change in percent body fat involves a change in the volume of large muscle groups, such as the legs. The volume achieved in resistance training is equal to the total workout load and energy expenditure of the workout.

The heart rate will be elevated, depending on the amount of resistance, the muscles involved, and the number of repetitions done. There does appear to be an adaptive response to this type of exercise that results in a reduction in the baseline heartrate, similar to that seen in aerobic exercise but not as profound as is seen aerobically.

Research has shown about an 11 percent decrease in baseline heart rate as the exercise becomes repetitive and ongoing.

There can be a dramatic increase in blood pressure that is seen to a greater degree in individuals who have hypertension. This suggests that this type of exercise should be done with caution in those who have underlying cardiovascular disease. The amount of blood pressure increase is dependent on the intensity of contraction, the time of contraction, and the amount of muscle mass involved in the workout. Things like circuit training with moderate resistance and high reps that also includes brief rests in between are associated with lower blood pressure readings.

There will be changes in heart size because of resistance training, particularly associated with an absolute increase in the left ventricular wall mass and septal mass. This may affect the stroke volume, cardiac output, and heart efficiency. There appears to be less of an impact on the left ventricular volume when compared to people who train aerobically.

There will be better metabolism of glucose with any type of exercise, although it is seen to a greater degree with aerobic exercise. The changes in body fat composition and decreased body fat seen in strength training will improve the glucose tolerance. Research has shown that individuals who engage in body building will have more favorable insulin sensitivity and improved glucose tolerance.

There is an endocrine response to resistance training. There will be an increase in both anabolic and catabolic hormones as an adaptation to this type of training. Growth hormone, insulin, and testosterone are the main anabolic hormones that will be increased with resistance training. On the other hand, catabolic hormones will also be produced with resistance training, such as cortisol, norepinephrine, and epinephrine. These will be effective over the short-term. Chronically, with adapted responses to resistance training, the resting level of testosterone will be increased and there will be an increased sensitivity of the tissue response to anabolic and catabolic hormones.

Resistance Training Prescription

In terms of prescribing resistance training as part of an exercise program, there are the things to consider:

- The program should include the greatest amount of energy expenditure per workout, using large muscle groups in order to improve mineral density and bone mass. This will increase the caloric expenditure in the workout, which will facilitate weight management.
- In most individuals, moderate intensities are recommended with many sets of 8 to 12 repetitions at a frequency of two to three times per week. The total workout volume, which is the total repetitions multiplied by the weight, should be increased over time.
- A progressive overload should be applied on an individual basis. What this means is that, when lifting a weight becomes relatively simple at 10 or so repetitions, there should be an increase in the weight applied rather than an increase in the number of repetitions.
- Be cautious with regard to the use of isometric contractions and high-intensity load training in those people who have a baseline of high blood pressure, as the blood pressure will increase to a significant degree with this type of exercise.
- Recommend a variety of exercises in order to prevent muscle soreness, overtraining, and injury in the individual who wants to maximize effectiveness of this type of exercise while minimizing the risk of injury.
- People who have arthritis, previous injuries, and hypertension should be monitored by a health professional so as to avoid exacerbating their injuries and/or illnesses.
- Pay attention to methodology and biomechanics when teaching these types of exercises to the new athlete. There are relatively safer and less damaging ways to perform these exercises that need to be begun from the beginning of the exercise program.

- Make use of rest periods between sets, particularly for new athletes who do not tolerate the rigors of this type of exercise if not done with adequate breaks between sets to settle the heart rate so as to allow the athlete to exercise longer and with greater weights applied.
- Allow for a recovery period of up to 48 hours, particularly in individuals who are just beginning an exercise program.

KEY TAKEAWAYS

- Anaerobic exercise makes use of creatine phosphate and glycolysis to make ATP energy.
- The energy used in anaerobic exercise can only last for about two minutes before aerobic energy systems kick in.
- A heart rate in excess of 80 percent of the maximum heart rate will lead to anaerobic exercise.
- Strength training is a type of resistance training in which the goal is to increase muscle mass versus just toning the muscles.
- Resistance training can involve free weight lifting, machine weight lifting, and the use of resistance bands, although things like swimming also have resistance training components.
- Resistance training has multiple long-term effects, including increased muscle fiber diameter, decreased heart rate, decreased percent body fat, improved glucose tolerance, and certain hormonal changes.

QUIZ

1. What form of metabolism is also referred to as lactic anaerobic metabolism?
   a. Creatine phosphate metabolism
   b. Amino acid metabolism
   c. Glycolytic metabolism
   d. Mitochondrial metabolism

   Answer: c. Glycolytic metabolism or glycolysis forms lactic acid as a breakdown product of the metabolism of glucose in the cytoplasm. This is different from creatine phosphate metabolism, which does not make lactic acid, and mitochondrial metabolism, which is aerobic in nature. Amino acid metabolism and fatty acid metabolism both go into aerobic pathways rather than glycolysis.

2. How long can glycolysis and creatine phosphate together provide ATP energy without the need for aerobic metabolic influences to exercise?
   a. 15 seconds
   b. 2 minutes
   c. 10 minutes
   d. 30 minutes

   Answer: b. This type of anaerobic metabolism is not capable of providing indefinite ATP energy and only provides energy resources for about two minutes of exercise.

3. In what way does anaerobic exercise promote weight loss?
   a. It increases muscle metabolism, which burns calories.
   b. It burns a great many calories per minute of exercise.
   c. It causes more ATP energy to be burned in the cells.
   d. It does not do much to promote weight loss.

   Answer: a. Anaerobic exercise promotes weight loss by increasing muscle mass, promoting muscle metabolism. Muscle metabolizes more calories per gram than is the case with fatty tissue so more calories are burned.

4. Cycling at a moderate rate with bursts of rapid cycling under increased resistance during the workout is called what?

    a. Sprints
    b. Plyometrics
    c. High intensity interval training
    d. Isometrics

    Answer: c. This form of exercise is referred to as high intensity interval training and can increase the heart rate for a brief period of time so that it reaches anaerobic levels for a short interval. This is a way to combine aerobic and anaerobic exercise.

5. The process of breaking down muscle in order to allow for recovery after resistance training?

    a. Catabolism
    b. Glycolysis
    c. Anabolism
    d. Osteogenesis

    Answer: a. The process of breaking down muscle in order to allow for recovery after resistance training is referred to as catabolism. Anabolism is the rebuilding of the muscle after the catabolic process.

6. A person of what age is most likely to benefit from resistance training?

    a. 10 years
    b. 30 years
    c. 50 years
    d. 70 years

    Answer: d. The older a person is, the greater are the advantages to doing resistance training. This means that, in the older person, the natural muscle mass loss is reversed, blood pressure can be normalized, balance is better, and osteoporosis is reversed so there can be fewer falls and fewer fractures from falls.

7. What is an advantage of using free-weights over weight machines?

    a. They allow for a wider range of weights to be utilized versus weight machines.
    b. They strengthen muscles to a greater degree than weight machines.
    c. They are simpler to use than weight machines.
    d. They allow for increased coordination versus weight machines.

    Answer: d. The only real advantage listed for those who use free-weights is that free weights allow for an increased coordination of muscles, which isn't seen when using weight machines.

8. What is not something gained by the athlete when using free weights?

    a. Coordination
    b. Proprioception
    c. Flexibility
    d. Muscle toning

    Answer: c. The main things that can be improved by using free weights are muscle strength, muscle toning, coordination, and proprioception. Flexibility is not a major benefit to using free weights.

9. Which areas of the body need to be loaded during resistance training in order to have this type of training affect the fracture risk in osteoporosis?

    a. Shoulders
    b. Knees
    c. Forearms
    d. Spine/hips

    Answer: d. The axial skeleton, which is mainly the spine and hips, must be loaded during resistance training if this type of training is to reduce the fracture risk due to osteoporosis.

10. Persons with which disorder or problem should be most cautious about doing resistance training?

    a. Osteoporosis
    b. Cardiovascular disease
    c. Fibromyalgia
    d. Obesity

        Answer: b. People who have cardiovascular disease and, in particular hypertension, should be cautious about resistance training because this type of training is associated with marked increases in blood pressure during the exercise.

Chapter 5: Aerobic Exercise and Aerobic Training

This chapter discusses the basics of aerobic exercise, the types of exercise involved in aerobic exercise, and the benefits of cross-training. The term “aerobic exercise” translates to “exercise with air,” implying that this is a type of activity that makes use of oxygen. Indeed, aerobic metabolism fuels aerobic exercise. There are many benefits to aerobic activities that differ from those seen in anaerobic exercise. Cross-training involves switching up activities in order to maximize performance, reduce injuries, and lessen boredom.

Aerobic Exercise

Aerobic exercise is also referred to as “cardio-exercise” because of its known benefits to the heart. The goal of this type of exercise is to increase the heart rate and breathing rate during physical activities over a sustained period of time. This type of exercise makes use of aerobic or cellular mitochondrial metabolism, which has the capability of making large amounts of ATP energy over a prolonged period of time as long as there is efficient use of oxygen.

As we will discuss in a few moments, the major difference defining aerobic exercise versus anaerobic exercise is the heart rate achieved. Refer to figure 17 again to see that the major goal of aerobic exercise is to achieve a heart rate of between 70 and 80 percent of maximum, sustained over an extended period of time, which is possible only because of the near indefinite ability of the mitochondria to make ATP energy in the presence of oxygen.

In aerobic exercise, to determine the target heart rate one must first calculate the maximum heart rate. This is, as you remember, 220 beats per minute minus the person’s age. This is the maximum used to calculate the 70 to 80 percent of heart rate necessary to maximize the efficiency of the aerobic exercise.

Diseases like cancer, depression, diabetes, heart disease, and osteoporosis can be decreased in incidence and improved because of this type of exercise. This is a type of exercise that often requires little in the way of equipment, although many athletes will use some type of indoor equipment (such as a treadmill) or outdoor equipment (such as a bicycle) to engage in this type of exercise.

By definition, aerobic exercise is a moderate-intensity exercise that is sustained for more than a couple of minutes. Remember that glycolysis can sustain exercise for about two minutes and, after that, aerobic metabolism is necessary and the activity becomes aerobic. While anaerobic exercise has the goal of building muscle, aerobic exercise is considered helpful for the cardiovascular system primarily, although gains can be made in weight loss, the respiratory system, and the musculoskeletal system.

In general, while one can monitor the heart rate during aerobic exercise, this type of thing is not necessary for the average non-athlete wishing to engage in aerobic exercise. Any exercise that results in a sensation of warmth, sweating, and mild shortness of breath would most likely be aerobic in nature. Common examples of aerobic exercise include bicycling, jogging, swimming, dancing, and even walking briskly.

Most of these exercises can be done both aerobically and anaerobically. A brisk walk of about three to four miles per hour will lead to mild shortness of breath and will be aerobic. Shifting to a higher speed of up to five miles per hour (unless the athlete is highly trained) will lead to increased shortness of breath and fatigue that becomes anaerobic in nature. This type of shift done intermittently during exercise is referred to as high-intensity interval training and can be helpful to gain muscle mass and burn extra calories without being a completely unsustainable anaerobic activity.

How Aerobic Exercise Occurs

Aerobic exercise starts with the delivery of oxygen. The lungs are the delivery organ for the oxygen necessary for this type of exercise. The breath rate increases in order to maximize the oxygen delivery, where oxygen is exchanged for carbon dioxide at the respiratory membrane. Red blood cells are necessary for oxygen transport and the increased heart rate pumps blood to a greater degree so as to provide the oxygen necessary for tissue utilization. Arterioles in the muscles will dilate in order to provide more oxygen to these tissues.

Oxygen consumption is the process of extracting oxygen from the blood by muscle tissue. This is done at a higher rate in athletes who are conditioned versus those that are deconditioned. This increase happens during chronic exercise training, which causes biological changes in the muscle. Later in this chapter, we will discuss the VO2max, which is the maximal oxygen consumption. This can be determined in the athlete. Deconditioned individuals have a VO2 in the range of 35 milliliters of oxygen per kilogram of body weight per minute. This value can be as high as 90 or more milliliters of oxygen per kilogram per minute in the elite athlete.

Because the main fuel in aerobic exercise is fatty acids, more fat is burned during aerobic exercise versus anaerobic exercise. Fat burning takes nine calories per gram to burn and carbohydrate burning takes five calories per gram. When oxygen is available, a higher percentage of fat is burned but, when anaerobic exercise is done, carbohydrates are the main source of energy.

The truth is that there are elements of burning both carbs and fat that occur at all times during exercise with more fatty acids used when the activity is primarily aerobic and more glucose used when the activity is primarily anaerobic. Some believe that it takes a minimum of 20 minutes or so to burn fat in aerobic exercise, when this just isn't the case.

Calculating the Target Heart Rate

There are more complex ways to calculate the target heart rate for aerobic exercise. This involves first determining the maximum heart rate, which is 220 beats per minute minus one's age. This is subtracted from the resting heart rate to get the heart rate reserve. Aerobic exercise is about 40 to 85 percent of this heart rate reserve. Add this percent back to the resting heart rate to get the target heart rate. Figure 18 shows how this is done:

Calculating the Target Heart Rate in Aerobic Exercise

1. Take 220 bpm minus the age = Max HR
2. Subtract Max HR from resting heart rate to get HHR (heart rate reserve).
3. Take HHR and multiply by 0.4 to 0.85 (depending on how hard you want to train).
4. Add this percent to the resting HR to get the target HR for aerobic exercise.

KNOWN BENEFITS OF AEROBIC EXERCISE

Aerobic exercise has more advantages to the athlete and exerciser than is seen in anaerobic exercise, although you will find that both types of exercise are recommended. The major benefits of aerobic exercise include the following:

1. Calorie burning—this will depend on the activity being done.
2. Enhances physical endurance—this means that the athlete will be able to exercise longer and will feel less cardiorespiratory distress while doing exercise.
3. Reduces the incidence of diabetes and heart disease
4. Reduces elevated blood pressure to a moderate degree.
5. Decreases the risk of developing breast and colon cancer in the future.
6. Improves heart attack survival rate should a heart attack occur.
7. Improves symptoms of depression to a moderate degree.
8. Reduces the percent body fat.
9. Increases HDL cholesterol, and is better than cholesterol medications in doing so.

10. Decreases arthritic symptoms.
11. Enhances balance and ability to perform activities of daily living for older athletes.
12. Decreases the blood triglyceride level.
13. Reduces weight and maintains a healthy weight.
14. Decreases insulin resistance, which improves glucose uptake in the cells, allowing for better glucose metabolism.

Many individuals want to know exactly how much aerobic exercise is necessary in order to gain the benefits. The current recommendations available come from the US Surgeon General and the American College of Sports Medicine. According to the Surgeon General, one should participate in about 30 minutes or more of accumulated moderate aerobic activity on at least five days per week. The emphasis here should be on "accumulated" exercise because, technically, a person can do this in two to three separate increments per day, adding up to 30 minutes daily.

According to the American College of Sports Medicine, one should participate in 20 to 60 minutes of continuous aerobic activity at 60 to 90 percent of maximum heart rate at three to five times per week, along with two to three days of resistance training. This recommendation does not consider cumulative activity to be as effective as continuous activity.

Calories Burned in Aerobic Exercises

Many people underestimate the number of calories burned in aerobic exercise. For this reason, it is a good idea to get an estimate of the number of calories burned per hour of physical activity. There are extensive lists of exercises and the number of calories burned per hour. In most cases, the calories burned depend on the weight of the athlete. The following list is of the calories burned per hour in a 150-pound athlete:

- Aerobic dance—450 to 500
- Outdoor cycling—540 to 620

- Stationary cycling—480 to 540
- Dancing—300 to 350
- Cross-country skiing—530 to 630
- Gardening—270 to 300
- Hiking—400 to 480
- Jogging—530 to 630
- Rope jumping—650 to 800
- Skating—470 to 550
- Running—650 to 750
- Swimming—400 to 480
- Tennis—470 to 550
- Walking—150 to 200 (at a regular pace)
- Walking—250 to 300 (at a rapid pace)

Safety of Aerobic Exercise

Aerobic activity is considered better than not exercising at all; however, some individuals should be careful about starting an exercise program because of the potential for preexisting conditions that preclude extensive exercise. Certain people should have a physical examination and possible an exercise stress test prior to participating in an exercise program. At risk individuals include the following:

1. History of a myocardial infarction (a heart attack) in the past
2. Known lung disease
3. Known heart disease
4. History of diabetes or similar metabolic disorder
5. Hypertension currently

6. Family history of sudden cardiac death before 55 in a close male relative or before 65 in a close female relative
7. History of heart attack or angina symptoms
8. Shortness of breath with exertion or at rest
9. History of dizziness or syncope
10. History of peripheral edema
11. Known palpitations at rest or with exercise
12. History of intermittent claudication (calf pain after short periods of activity that resolves with rest)
13. History of heart murmur

Some of these individuals will simply need an exam or exercise stress test, while others will need expanded testing, such as a pulmonary function test (for lung disease), echocardiogram (for heart murmurs), stress echocardiography (for heart failure or heart murmurs), or Doppler ultrasound studies of the arterial system of the legs (for claudication).

Recommendations for Aerobic Exercise Programming

The most important exercise recommendation for the new athlete is to assure the individual chooses an aerobic exercise program they enjoy doing so as to maximize their ability to stick to an activity. The Surgeon General's recommendation or the American Academy of Sports Medicine recommendation can be followed, depending on the individual's schedule and abilities. Small amounts of exercise can be introduced until the exercise can be tolerated for longer periods of time.

A five-minute warm up is recommended, involving starting slowly and increasing activity after the muscles warm up. In addition, a three to five-minute cooldown period is recommended. This will result in less dizziness from the pooling of blood in the legs after exercising heavily. Stretching before and after exercise is also a good idea, depending on the type of activity done and the amount of tension there is in the muscles.

Effects of Aerobic Exercise

While at rest, the average adult breathes in and out about seven to eight liters of air per minute. This allows plenty of oxygen to be taken up by the alveoli in order to go to the heart to be pumped to the rest of the body. Exercise over the short-term will have positive effects on the energy, respiratory, cardiovascular, and muscular systems.

- With the cardiovascular system, the short-term effect is to increase blood pressure, increase cardiac output, increase heart rate, and increase stroke volume.
- With the respiratory system, there will be an increased tidal volume and breath rate. The amount of oxygen taken up will be higher as will the rate of carbon dioxide removal.
- Lactate production will increase, even with aerobic exercise, mostly due to lactate production in the glycolytic process.
- Muscles will have an increase in temperature and will be increased in pliability. Muscle fatigue can happen over the short-term, particularly when the systems aren't completely functioning to have aerobic respiration that affect ATP production. As with anaerobic exercise, the muscles need rest adaptation, and recovery or they risk injury.

The long-term effects of aerobic exercise also affect the major systems—many of these being long-lasting. These include the following:

- There will be hypertrophy of the heart muscle, an increased stroke volume, a decreased resting heart rate, and increased capillary formation in both the lungs and muscles. The smooth muscle walls of the arteries and veins become more elastic so that the resting blood pressure will decrease. The cardiac output is the stroke volume times the heart rate so, with an increased stroke volume, the resting heart rate will naturally decrease because more blood is put out per beat.

- The lungs will have an increased vital capacity with greater recruitment of functioning alveoli. The respiratory muscles will increase in strength with an increased lung volume and total lung capacity.
- The tolerance to lactic acid is improved over time with an increased production of ATP energy through aerobic metabolic increases.
- Muscles will hypertrophy when the activity includes some degree of resistance. The same is true of skeletal system density. The bones will also increase in density if there is a resistance component to the exercise program.
- The increase in capillary numbers will occur both in the lungs and in the muscles. Because capillaries are necessary for gas exchange and because these are places where an improvement in gas exchange is necessary, these are where the capillary beds are increased.

More on Aerobic Exercise Types

There are several exercise types that qualify as being aerobic exercises. Walking is an aerobic exercise that can be done by nearly everyone. It will have all of the positive effects of aerobic exercise with the addition of having stronger leg muscles. This is a relatively low-impact exercise that can even be done in individuals who are overweight, pregnant, or under-conditioned. Walking briskly and pumping the arms will increase the calories spent by up to 10 percent. Walking for weight loss requires up to an hour per day in order to be effective.

Running also requires no equipment and will have the added benefit of increased cardiovascular health over walking. It burns more calories per hour than walking so that half the time spent running will result in the same calories burned versus walking. Most people jog rather than run because it can be sustained for longer periods of time by more athletes without resulting in a shift toward anaerobic metabolism. The impact is of course higher than with walking so that injuries can occur. Knee injuries, ankle sprains, and shin splints are more common with running. Running or jogging on dirt or grass will decrease the injury rate as will well-fitting shoes.

Swimming is particularly good as a low-impact aerobic sport. It can be done in hot water and by individuals with back or other joint problems. There is a decreased risk of joint, muscle, and ligament injuries with swimming. Because it doesn't involve weight-bearing, it does not improve bone density as much as walking or running. It also doesn't have as significant effect on weight as is true of running or walking.

Cycling has the advantage of enhancing leg muscle strength and tone as well as buttock muscle toning. There is less risk of injury to the joints and bones because it is lower-impact when compared to running and walking but still burns a great many calories. Spinning classes burn a great deal many calories over regular cycling.

Rowing is a good aerobic exercise for cardiovascular fitness as well as strengthening of the abdominal, back, and upper body muscles. Outdoor rowing can be fun if available, while indoor rowing machines are also effective with changes in tension possible to increase the load on the muscles. Technique is important to avoiding injuries.

Aerobic classes or "cardio" classes are available at fitness centers and gyms. This involves physical activity over an extended period of time, usually to music, designed to raise the heart rate and keep it up. The intensity varies with the class and there can be an increased chance for ankle or knee injuries when the intensity is too high. It is also something that is usually done with others so there is a social component as well.

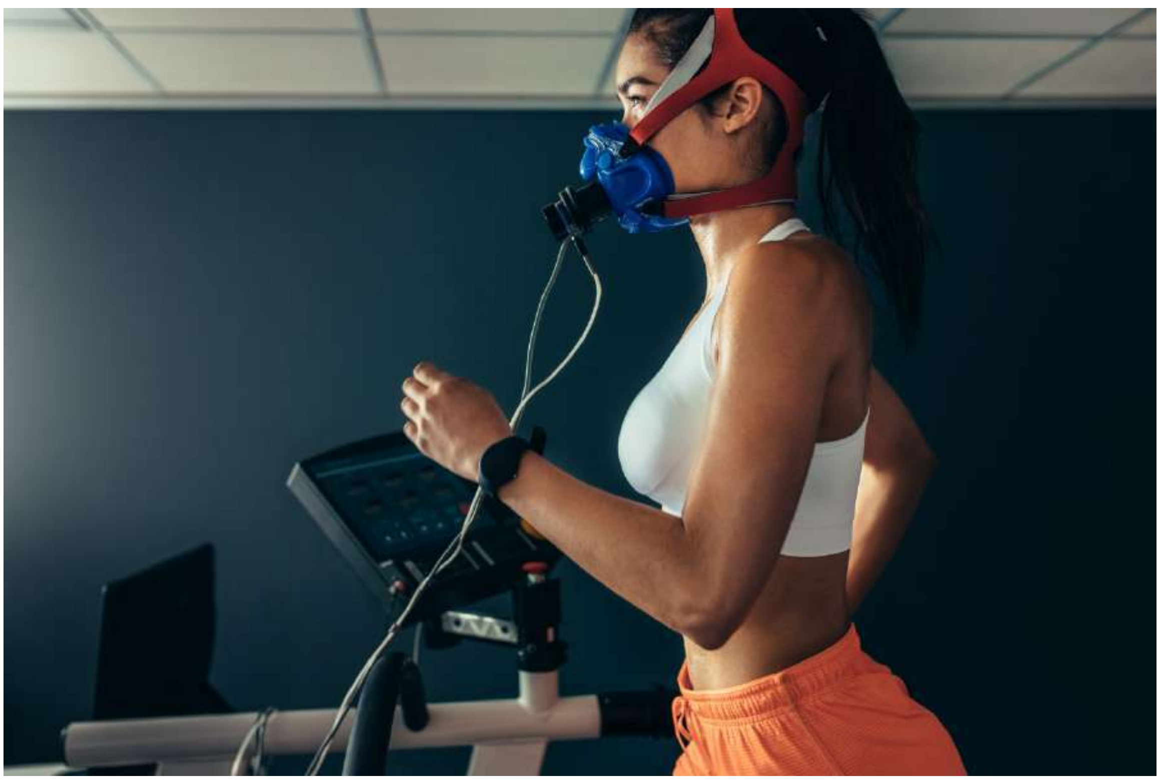
Dancing is also a good social aerobic exercise. There is a variety of different classes that can involve dancing and it can be done in an evening out. Because it is usually an indoor sport, it doesn't depend on the weather. It usually doesn't involve any special equipment with the possible exception of dancing shoes.

Exercise Testing

As mentioned, there is testing that might be done before starting an exercise program or for seasoned athletes who want to assess their exercise capacity. One of these is the cardiac stress test or "exercise stress test." In this test, the individual has cardiac electrodes placed on their chest and will have a baseline electrocardiogram or ECG done. If this shows no evidence of ischemia to heart muscle (or lack of oxygen to the muscle), the individual is asked to walk on a treadmill while the ECG is running.

The treadmill speed and incline are increased so that the target heart rate can be achieved. If the target heart rate is achieved without evidence of cardiac ischemia, the individual is cleared for aerobic exercise. It can be done alone or with an echocardiogram performed after the exercise. This ultrasound of the heart will detect limitations in heart muscle movement after exercise and will further detect a lack of blood flow to the heart muscle.

Another test that can be done is a VO2 max test. This measures the maximal amount of oxygen that is used during intense exercise. It is an assessment that can be done anytime during an athlete's training in order to measure their aerobic endurance. The VO2 max is measured in milliliters of oxygen per kilogram of body weight per minute. The idea behind the test is that a higher VO2 max means a greater ability to generate ATP in the cells. Figure 19 shows a VO2 max test:



The test can be done on a treadmill or stationary bicycle. A face mask is applied that will measure the respiratory rate, respiratory volumes, oxygen concentration inhaled, and CO2 exhaled. Heart rate is measured as the individual exercises, using a chest strap. The VO2 max is the point at which an increase in activity does not change the oxygen consumption and there is a shift from aerobic to anaerobic metabolism.

The scores will establish the athlete's baseline fitness level before the start of training and as training progresses. There are algorithms that will determine the VO2 max, which varies with gender and age. The VO2 max is higher in men, younger individuals and trained athletes. A poorly-trained individual who is older than sixty will have a VO2 max of about 17 to 20 milliliters per kilogram per minute. A highly trained young athlete will have a VO2 max of between 42 and 56 or higher levels. The averages are about 30 milliliters per kilogram per minute for women and about 35 milliliters per kilogram per minute for men.

Factors that influence the VO2 max include the altitude. Athletes will have a five percent decrease in VO2 max at higher altitudes. Individuals who participate in endurance sports like cross-country skiing, long-distance running, cycling, and rowing will tend to have a greater VO2 max because they have gained a great deal of aerobic capacity with training.

Lactate threshold testing is another test that can be done in athletes trying to maximize training. This is the point during maximal exercise at which lactate increases in the blood because it builds up faster than it can be eliminated. This lactate threshold happens at about 50 to 80 percent of the VO2 max level. It is marked by a slight decrease in pH level of the blood and will result in rapid fatigue and decreased muscle power. A higher threshold will mean a longer period of time until exhaustion.

The lactate threshold test is done similar to a VO2 max test with a treadmill or stationary bicycle. Intensity of the exercise is increased every five minutes with fingerstick measurements at the end of each period that measure the blood lactate concentration. It continues until there is a spike in lactate levels and, because the VO2 max is also tested, it is measured as a percentage of the VO2 max. The amount of power being performed at the lactate threshold is determined in order to design training programs.

The average person reaches their lactate threshold at about 60 percent of the VO2 max. Athletes who exercise recreationally will reach the lactate threshold at 65 to 80 percent of the VO2 max, while elite athletes reach their lactate threshold at 85 to 95 percent of their VO2 max.

Adaptation to Aerobic Training

The VO2 max will increase with an increase in endurance training. There is an upper limit to the amount of oxygen that can be delivered to the cells, based on the cardiac output and the ability to extract oxygen by the cells. Training will increase the cardiac output as well as the number of mitochondria in the cells. Other things that improve the aerobic capacity are the muscle blood flow, vasodilation of muscle arterioles, and the number of muscle capillaries.

The cardiac output increases with aerobic activity, mostly because the stroke volume increases so more blood is pumped per beat. The thickness of the heart muscle also increases with training. There will also be an increase in the proteins that can participate in oxygen consumption. Some of these proteins are associated with the increase in mitochondrial numbers. Increases of up to 50 percent of baseline can also affect the VO2 and aerobic capacity.

Cross-training

Cross-training involves using several different types of activities in order to maximize overall fitness. There are several benefits of cross-training. One of these is reduced risk of injury. By doing different activities, there is less stress on the joints and muscles the athlete usually exerts during their preferred training activity. Athletes who participate in running, for example, will often do elliptical training, swimming, or cycling as ways to enhance physical fitness without putting stress on the joints and lower extremity bones.

Cross-training will enhance weight loss. Weight loss is better accomplished when exercising for longer periods of time—something that might not be possible while performing one activity alone. More weight can be lost by cross-training, which will not stress the same muscles over and over again.

These types of activities will improve overall fitness and aerobic conditioning. Resistance training as part of cross-training will improve muscle strength in individuals who mainly exercise aerobically. Increased muscle strength through cross-training will also prevent injuries in high-level athletes. Cross-training can also prevent boredom that can happen when doing the same exercise over time. This will enhance adherence to the exercise program. When injuries do occur, cross-training can allow for ongoing training through the injury.

Key Takeaways

- Aerobic exercise takes mainly fatty acids and metabolizes them in the mitochondrial energetic pathways.
- Aerobic exercise will exercise the heart to about 70 to 80 percent of maximal heart rate.
- Aerobic exercise affords many benefits to the heart, lungs, cancer risk and overall fitness.
- Individuals with certain diseases or risk of diseases should be assessed before starting aerobic exercise.
- The VO2 max will measure aerobic capacity and the lactate threshold is when there is more lactic acid produced than can be eliminated.
- The heart, lungs, blood vessels, and muscle cells adapt to prolonged aerobic exercise.
- Cross-training is something done by many athletes in order to prevent injury, break up boredom, and allow for exercise through injury. It will also help promote weight loss by being able to exercise longer.

QUIZ

1. What is the primary source of ATP energy in aerobic exercise?

    a. ATP reserves
    b. Creatine phosphate
    c. Glycolysis
    d. Mitochondrial metabolic pathways

    > Answer: d. Mitochondrial metabolic pathways, which include the Krebs cycle and electron transport pathways, collectively called "aerobic metabolism," involve the ongoing breakdown of glucose into CO2 and water using oxygen.

2. At what target heart rates does aerobic exercise happen?

    a. 50 to 60 percent of maximum
    b. 60 to 70 percent of maximum
    c. 70 to 80 percent of maximum
    d. 80 to 90 percent of maximum

    > Answer: c. Aerobic exercise happens most between 70 and 80 percent of the maximum heart rate. This is the goal heart rate for those practicing aerobic exercise. Above this level, the exercise becomes anaerobic and below this level, the exercise might be fat-burning but is less efficient as an aerobic activity.

3. How many minutes at a minimum qualifies as aerobic exercise?

    a. 1 minute
    b. 2 minutes
    c. 10 minutes
    d. 20 minutes

    > Answer: b. Reserve ATP energy and glycolysis will last for the first two minutes of an exercise event; however, after the first two minutes,

aerobic metabolism takes over and the exercise automatically becomes aerobic.

4. What is least responsible for the increase in oxygen delivery to tissues during aerobic exercise?
   a. Increased heart rate
   b. Increased respiratory rate
   c. Vasodilation of muscle arterioles
   d. Increased red blood cell count

      Answer: d. Each of these is helpful in providing an increase in oxygen delivery to tissues, except for an increased RBC count. An increased RBC count happens over time and does not reflexively increase in response to exercise. Some athletes do, however, use blood doping techniques to increase their RBC count so as to give them the competitive advantage.

5. What is not considered a benefit of aerobic exercise?
   a. Reduces total cholesterol levels.
   b. Improves glucose tolerance.
   c. Decreases risk of certain cancers.
   d. Reduces percent body fat.

      Answer: a. While aerobic exercise can do each of these things, it is mostly known for decreasing the triglyceride level and increasing the HDL level rather than lowering the total cholesterol level.

6. What is not a key feature of the US Surgeon General recommendation for aerobic exercise?
   a. Five days a week of aerobic exercise
   b. Exercise can be cumulative
   c. Two days a week of resistance training
   d. Thirty minutes of moderate exercise

Answer: c. The surgeon general's report indicates that aerobic activity can be cumulative for 30 minutes a day and for five days a week. It does not give recommendations for resistance training, which is included in the American College of Sports Medicine.

7. An individual planning on starting an exercise program has calf pain when walking a block. What pre-exercise test would be most helpful to perform prior to exercise?

   a. Exercise stress test
   b. Echocardiogram
   c. Doppler ultrasound
   d. Exercise echocardiography

   Answer: c. A Doppler ultrasound is done to evaluate the flow of blood through the leg arteries and will be able to detect peripheral vascular disease in the individual, which can be managed prior to starting an exercise program.

8. What is not a long-term effect of aerobic exercise?

   a. Increased lung capacity
   b. Increased bone density
   c. Decreased resting heart rate
   d. Increased cardiac output

   Answer: b. The increase in bone density will occur with anaerobic or resistance training but will not necessarily occur with aerobic exercise alone. The lung capacity and cardiac output will increase with a concomitant decrease in heart rate at rest.

9. What is measured when a person has an exercise stress test?

   a. Aerobic capacity
   b. Oxygen uptake by the lungs
   c. Heart muscle ischemia
   d. Cardiac output

Answer: c. An exercise stress test will measure heart muscle ischemia when the person exercises up to their target heart rate. If there is no evidence of ischemia at maximal exercise, the individual can generally safely start a program of aerobic exercise.

10. What are the units for the VO2 max when tested in humans?

    a. Milliliters per minute of oxygen
    b. Milliliters per kilogram per minute of oxygen
    c. Milliliters per minute of ATP produced
    d. Liters per minute of oxygen up take

    Answer: b. The VO2 max is done in units of milliliters per kilogram per minute of oxygen taken up before the aerobic metabolism becomes anaerobic metabolism.

Chapter 6: Exercise in Temperature and Altitude Extremes

This chapter talks about exercise in extremes of temperature and altitude. Many athletes cannot exercise in temperate weather all the time and need to adjust their workouts to make accommodations for extreme cold or extreme hot weather. There are specific bodily responses to exercising in these extremes that need to be taken into account when working out. The chapter also talks about hot yoga, in which individuals practice yoga under conditions of high heat and humidity. High altitude exercise has received a great deal of attention among elite athletes, who train at higher altitudes to help them perform better at lower altitudes; this is another component of this chapter.

Exercise in Cold Weather

According to the American College of Sports Medicine, exercise can be performed safely in many cold-weather environments without significant risk of injury. This is not to say, however, that exercise in cold weather has positive effects. On the other hand, exercise in cold weather is preferable to not exercising at all.

Low temperatures put a greater load on the athlete's metabolism. As temperature falls, the blood pressure increases because blood is shunted away from the skin surface, which increases the amount of blood that is present in the core. This places extra stress on the heart as it pumps more blood through a smaller blood network.

The body also must work harder to maintain a normal body temperature. This involves increasing the metabolism in order to maintain body heat by using glucose energy. This will, of course, decrease the amount of glucose used for muscle contraction, decreasing the efficiency of the muscles. Even before exercising, the body is working harder than it does at normal temperatures just to remain warm.

When the muscles are colder, the enzymatic reactions will take place more slowly. The reaction rates will be cut in half for every 10 degrees Celsius in a reduction in temperature. The body will do what it can in order to maintain a normal core temperature, even at the expense of the rest of the body. The arm and leg muscles will be effected most as blood is shunted away from these muscles to keep the core temperature up.

Remember that there is a mixture of fast glycolytic (fast-twitch) and slow oxidative (slow-twitch) fibers. The slow twitch fibers do more aerobic work than fast twitch fibers. When there is a decrease in efficiency, all of the muscles participate in exercise, including the fast twitch muscles. The fast twitch fibers will produce more lactic acid than slow twitch muscles, which leads to an excess in acid production and sore, or "stiff," muscles.

When more lactic acid is made, there will be an increased metabolic load on the body as a whole and a greater oxygen debt that must be made up for by decreasing output or stopping altogether. It means that the muscles will be weaker and the athlete will have less overall stamina.

Other factors that come into play with exercise in colder environments include an increased danger of getting a pulled muscle. While this can be mitigated by warming up before exercise, the muscles also cool down faster and are more difficult to warm up in the first place. There is also a slowed reaction time of the nerves to the muscles because of slower enzymatic reaction times in the nerves. This leads to a decrease in reaction time.

Carbohydrates tend to be used more quickly in cold weather because this is the type of energy the fast twitch fibers make use of. This means that the glycogen gets depleted during a time when energy consumption is up, leading to a decrease in stamina. Fat and protein oxidation as a form of energy takes longer to mobilize, so that the fastest way to get energy (glucose and glycogen) gets utilized preferentially, leading to a loss of these sources of energy faster.

Sweating and warmth serves as a reminder to replace lost fluids in exercise. In the cold weather, this mechanism doesn't work as efficiently, leading to a greater degree of dehydration in cold environments versus warm environments. Cold drinks are also not considered as refreshing in the cold so there is less of a temptation to drink.

While there is less water lost through sweating in cold weather, the water loss from breathing is markedly enhanced. Warm air holds more water vapor so the air will bring moister air to the lungs. The dry air of cold weather results in more water necessary from the body to have moist air in the alveoli. This moist air is breathed out and moisture is lost through the lungs. This makes hydration important in cold weather.

Dangers of Exercising in Cold Weather

There are several dangers imposed upon the body by exercising in cold weather. Many of these dangers can be mitigated by wearing the proper clothing while exercising outdoors when it is cold. Even though there is an increase in body heat produced while exercising, hypothermia can set in, particularly when the clothing gets wet. It is not necessary to have temperatures below the freezing point for hypothermia to develop.

In hypothermia, the body temperature decreases from 37 degrees (which is normal) to 35 degrees or less. The first sign of hypothermia is shivering, along with numbness of the extremities, poor dexterity, and a feeling of cold. Complex tasks will become more difficult and decision-making becomes impaired by poor judgment.

As hypothermia worsens, the heart and breathing rates slow down as less oxygen is required by the tissues of the body. The skin will be pale and the pupils become dilated and nonreactive to light. Metabolism slows markedly and the person may appear to be dead, breathing one to two times per minute. Heart arrhythmias begin at a core temperature of 28 degrees Celsius so that the heart does not pump with a normal rhythm. At 20 degrees, the heart stops beating altogether. Without urgent medical intervention, death ensues.

Frostbite and frost nip can occur at low temperatures. These happen when the blood flow diminishes to the skin in order to prevent heat loss to the rest of the body. With frost nip, the nose, cheeks, ears, fingers, and toes turn pale from a lack of circulation. It often cannot be felt but can be noticed by looking at the skin; it must be treated by covering the affected area in order to warm it. Rubbing will only damage the tissue and should not be used. The best treatment is getting indoors.

Frost bite involves crystals forming inside the body cells, which kill the cells in the same way as a burn will do. It can be very painful as the skin and tissue warm up. Deep tissue frostbite can lead to a loss of part of the body, in particular, fingers, toes, or entire limbs, depending on the degree of frostbite to the tissues.

The wind chill needs to be factored in when looking at the damage to the body in cold weather. While a breeze can feel refreshing, it will only contribute to the risk of hypothermia and other cold-related injuries. A minimal increase in wind will have a great effect on the ability to stay warm while exercising.

The main benefit to exercising in cold weather is that more calories are expended for the same amount of exercise done. The body revs up the metabolism in order to stay warm so there is more fat burning occurring as long as the athlete doesn't make up for the energy expenditure by eating more calories.

Athletes who Should Not Exercise in Cold Weather

There are extra stresses placed on the body that may not be tolerated by all individuals, particularly those who have underlying health problems or aren't already somewhat physically fit at the time they start exercising outdoors in winter. People with these health problems should avoid exercising outdoors or should take special precautions in cold weather:

- Heart conditions—there is extra strain put on the heart when exercising in cold weather. This is something that may not be well tolerated in the athlete who has an underlying heart problem.
- Asthma—cold weather will contribute to bronchospasm, even in the relatively healthy athlete. Individuals who have underlying asthma will be more likely to have narrowing of the airways and difficulty breathing in colder environments, especially when exercising.
- Exercise-induced asthma—there are some individuals who do not have true asthma but will have bronchospasm and narrowed airways when they exercise.

This will be a person who has bronchospasm with any type of exercise but will be particularly affected in the cold.

- Raynaud's disease—these are individuals who have restriction of circulation when their extremities are exposed to the cold that is beyond that seen in the average person. This can lead to a greater chance of developing frostbite in the upper extremities.

Tips for Working Out in Cold Weather

There are certain things that will improve the ability to successfully work out in cold weather. Much of this involves dressing properly for the season. The wearing of layers is important. The innermost layer should be synthetic with a fabric that wicks moisture away from the skin. The second layer should be an insulator, such as wool or fleece. The third layer should be a breathable, yet waterproof layer that can repel wind and water. Cotton should be avoided as it doesn't insulate when wet. A warm change of clothing is also recommended after a cold-weather workout.

Because the blood flow remains concentrated in the core, the limbs are more susceptible to the adverse effects of cold. Thermal or wool socks are recommended as well as gloves. Heat is easily lost through the head so wearing a hat is important. If not wearing a face mask or scarf over the face, sunscreen should be applied because, even in the cold UV rays are present in sunny weather.

Wind and rain are a bad combination when working out in cooler weather. Water draws heat from the body at a rate that is 25 times faster than air. When wind is added to this, the effect is enormous losses of heat energy from the body. Rain and wind will push the moisture through the clothes, ultimately wetting down the inner layers and possibly the skin.

On the other hand, overdressing can be a problem. If the athlete gets too warm during the workout and increased sweating occurs, there can be a greater loss of heat that negates the fact warmer clothing is being worn.

Hydration and nutrition are important when working out in cold weather. It doesn't help to hydrate beforehand because going out in the cold often gives rise to the need to urinate when coming from a warm environment. Hydrating during the workout is best. Nutrition, however, should be attended to in advance with a starchy meal a few hours before working out. The carbohydrates will release sugar slowly and fuel the workout. Eating a high-carb food during the workout is also beneficial when working out for a longer period of time.

Exercise in Hot Weather

There are two major things to consider when exercising in hot weather or in other hot environments. These are dehydration and increased body core temperature. Exercise generates heat and unless the heat is eliminated properly, complications can occur. An increase in body temperature will lessen muscle endurance because of a shift from aerobic to anaerobic metabolism. As you know, any time the metabolism shifts to anaerobic metabolism, the ability to exercise for long periods of time will diminish.

Even when the athlete uses energy bars, gels, and sports drinks, the intake cannot keep up with the rate of energy loss in hot and humid conditions. Blood pools in the legs in high heat situations, which means that the heart does not get enough preload and will not put out an effective cardiac output so the blood supply to the muscles diminishes.

Dehydration will be another thing that is a bigger problem in hot weather while exercising. The dehydration is insidious and will occur before muscle cramps set in. High-intensity exercise will result in a loss of up to eight percent of the body weight, with an inability to absorb fluid at a rate that keeps up with the loss. The VO2 max will decrease with dehydration because the body cannot use oxygen as effectively.

Stages of Heat-related Illness

There are three stages of heat-related illness, which is brought on by dehydration and an increase in body temperature. The first stage is heat cramps. This involves the cramping of the calves and abdominal muscles because of a loss of sodium from the muscle cells.

The muscle cramps can be involuntary and spasmodic. A low sodium concentration in the bloodstream is a common finding.

The next stage is heat exhaustion. This happens when further dehydration ensues at high ambient temperatures. The main symptoms include the following:

- Nausea and vomiting
- Shortness of breath
- Fatigue and weakness
- Dizziness and unsteadiness
- Sweating
- Ongoing muscle cramps
- Headache

Individuals who are older, younger, or have high blood pressure are at greater risk of developing heat exhaustion. The body attempts to regulate the body temperature as much as possible but this is at the expense of other body functions. There is a sudden decrease in exercise performance in the athlete. Treatment involves replacing fluids and removing clothing layers in order to cool the body down over a relatively rapid period of time.

Heat stroke is the third stage of dehydration and heat injury. In this case, the body temperature rises to about 39 degrees or higher. The sweating mechanism is impaired so there is hot, dry skin instead. Confusion, disorientation, and bizarre behavior are common. The heart rate is elevated with palpitations. The athlete will also have nausea, vomiting, dizziness, and syncope (fainting).

High-risk individuals are those who are exercising outdoors, elderly, or severely obese. Certain medications will impair the body's ability to sweat. Children and those with heart failure have a decreased cardiac reserve, which inhibits the heart's ability to respond to severe degrees of dehydration.

Heat stroke can be deadly so the treatment needs to be immediate. It involves cooling the body as rapidly as possible and giving intravenous fluids in order to reduce the body temperature in order to lessen the impact of what can be permanent brain damage and other damage to end organs.

Sweating has a protective mechanism in heat exposure during exercise but it can lead to dehydration if the sweat has not been replaced with oral fluids. As much as 60 percent of the human body consists of water. Only about 10 percent of this will be found in the bloodstream. During intense exercise and with a lot of sweating, up to three liters of sweat can be produced—fluid that is lost in the bloodstream first and then in the tissues unless replaced during and after working out.

During exercise and with hot temperatures, the blood flow can triple to the skin tissues. This leads to sweating that is more prominent in humid conditions because the sweat doesn’t evaporate and cool the skin properly. This only leads to more sweating that will quickly cause dehydration. People with weak hearts may not be able to keep up with the dehydration and, with maximal dilation of the skin vessels, it may still not be enough to let heat out of the body.

For the athlete, fluid replacement is critical. Fluids need to be replaced before, during, and after the workout, even when the athlete does not feel thirsty. This is because thirst is not a good predictor of dehydration and will occur after dehydration has already set in. In addition, thirst can often be satisfied with just a few sips of water, which isn’t enough to correct water losses in the body. Even with adequate fluid replacement, the level of activity should be decreased in hot and humid conditions.

It is not necessary to replace with electrolyte solution throughout the exercise. About a liter of water should be taken in before exercise with a liter of water taken in for every hour of exercise. After exercise, an electrolyte solution can be used, with about half a liter consumed shortly after the workout.

Loose-fitting clothing is better than clothing that is constricting. Direct sun exposure should be avoided and salt tablets should not be used because they make dehydration worse. Cool water is better than cold water because it absorbs better and still cools the body. Juices and sodas should not be used in exercise because the carbohydrates don’t absorb well during the exercise process. Sports drinks just add extra calories, especially in workouts lasting less than 90 minutes.

As in cold-weather exercise, sweat-wicking clothing is recommended. Dark clothing should be avoided and as few layers as possible are recommended. If padding or helmets are necessary, extra precautions against the heat are recommended. UV-blocking sunglasses should be worn as well as sunscreen that is water-resistant against sweat and water sports. Sunburn will decrease the body's ability to cool itself so it should be avoided when possible.

Hot Yoga as an Exercise

We haven't discussed yoga as a form of exercise, which involves components of flexibility and resistance training. Bikram yoga is performed in a room kept at 40 percent humidity and 105 degrees Fahrenheit or 40 degrees Celsius. All muscle groups are used with demanding poses that are intended to exercise the muscles and increase the heart rate. Both the extremes of temperature and the workout have the potential to contribute to heat-related illness.

Individuals who have heart disease, heat intolerance, a history of dehydration, or known problems with heatstroke in the past should avoid hot yoga. Those who start this program should hydrate throughout the workout in order to avoid heat injury. It has real benefits if done correctly as it not only increases the flexibility, it improves cardiovascular fitness. The end result is an increase in metabolism that burns extra calories.

The heat generated in hot yoga will increase the basal metabolic rate, making the enzymes affected in metabolism work faster and more efficiently. Brief exposures to high temperature will not raise the basal metabolic rate very effectively but the prolonged session of hot yoga can raise this rate to a significant degree. This has been found in research studies to reduce the athlete's body mass index to a significant degree.

Exercise at High Altitudes

Athletes will either exercise at high altitudes because they plan to be competing at high altitudes and need to acclimate or because they are using altitude to improve their performance at normal altitudes. High altitude training is defined as training about 1500 meters elevation or about 4921 feet elevation above sea level. High altitude normally makes physical activity more challenging but, after acclimatization to the altitude, the athlete will adapt in order to perform better.

High altitude does not mean that the oxygen level is less. All air at any altitude is about 21 percent oxygen, 79 percent nitrogen, and 0.03 percent carbon dioxide. What does differ in higher elevations is the partial pressure of oxygen. The air isn't as dense so the partial pressure of oxygen and the entire air pressure is reduced.

The air pressure at sea level is 760 millimeters of mercury but, at the top of Mount Everest, the air pressure is just about 231 millimeters of mercury. This reduction in the pressure means less of a pressure gradient across the alveoli so oxygen doesn't diffuse as quickly as the respiratory membrane. Because the partial pressure of oxygen is less on Mount Everest, many athletes require supplemental oxygen.

Respiratory System and Altitude

Above 1500 meters, there begins to be effects of elevation on athletic performance because the cardiovascular, metabolic, and respiratory systems are affected. With regard to the respiratory system, the respiratory rate will increase, even at rest. More ventilation needs to occur if the same amount of oxygen is going to be taken up by the lungs.

Oxygen diffusion is decreased—below the 98 percent oxygen saturation level of hemoglobin. Because the pressure gradient drops, the percent oxygen saturation is about 90 to 92 percent at 2500 meters. This pressure gradient is also decreased at the tissue level because there is less oxygen in the blood to diffuse into the tissues.

The VO2 max decreases at high altitudes. This begins at about 1600 meters elevation and drops about 10 percent for every 1000 meters higher so that an athlete with a VO2 max of 60 milliliters per kilogram per meter will drop their VO2 max to about 15. Those with a VO2 max of less than 50 milliliters per kilogram per minute will have a VO2 max in the range of five, which is just enough to support oxygenation at rest.

Cardiovascular System and Altitude

The cardiovascular system changes with altitude. The plasma volume will decrease by as much as 25 percent within a few hours after increasing in altitude and doesn't normalize for several weeks. Plasma is the liquid component of blood; it decreases in order to increase the red blood cell density. The hematocrit or amount of hemoglobin per unit of blood goes up so there is an increased oxygen transport for a given cardiac output.

The stroke volume decreases because of the reduction in plasma volume, which happens in the first few hours after arriving at high altitudes. The heart rate will increase in order to compensate for this, which has the effect of raising the cardiac output at rest a little bit. After a couple of days, the extraction of oxygen is more efficient, so the cardiac output normalizes. After about ten days, the cardiac output will decrease.

During exhaustive exercise, the stroke volume and maximal heart rate will decrease. This decreases the cardiac output at maximal activity and hinders endurance, especially as the respiratory system changes are also happening to drive down the VO2 max.

Both the respiratory and cardiovascular system effects at higher elevations cause less effectiveness of aerobic respirations and greater reliance on anaerobic metabolism and an increase in lactic acid production, even at sub-maximal exercise levels. This has a greater effect on athletes who are participating in endurance athletics and less of an effect on resistance sports. Because the lactic acid levels are not as elevated at maximal effort, anaerobic athletes can improve their outcome because there is less aerodynamic effect from the thinner air.

HIGH ALTITUDE ACCLIMATIZATION

It takes about two weeks for the athlete to adjust to the hypobaric (low pressure) situations seen in high altitudes. Every increase of 2000 feet above 7500 feet (that of Mexico City) takes an additional week of acclimatization. Even with complete acclimatization, however, there will never be the same degree of aerobic endurance or power that can be achieved at sea level. There are, however, adaptations that do occur with time.

The total red blood count increases. The altitude increases the erythropoietin level in the bloodstream, which is the hormone necessary for RBC production. This level peaks at 24 to 48 hours after arriving at high altitudes. The hematocrit, however, takes weeks to respond to high elevation. Pulmonary ventilation will stabilize but is increased with exercise and at rest compared to being at sea level.

The submaximal-effort cardiac output decreases to below sea level values because the hemoglobin amount increases so there is more oxygen-carrying capacity in the blood and less burden on the heart. Muscle diameter decreases over a four to six week period of time—both in the fast and slow twitch fibers. Some of this decrease may be seen because of the decreased appetite seen in higher altitudes.

PREPARING TO COMPETE AT HIGH ELEVATIONS

The athlete preparing to compete at high altitudes has several options. The first is to compete immediately (within 24 hours) and not to acclimatize. This leads to fewer problems with altitude sickness, which don't happen until the athlete has been there for a while. The second option is to train at higher altitudes for at least two weeks before competing. Most of the changes that happen will occur in this time, even though it takes about four to six weeks for maximal acclimatization. The third option is to maximize endurance at sea level to accommodate for the lower VO2 max that will be seen at higher altitudes.

Some athletes purposely train at high altitudes so that they can have better oxygen carrying capacity when they ultimately compete at lower altitudes. This is not completely well-established but is a practice that many elite athletes adopt in order to have a competitive edge. Weight loss is unavoidable at very high altitudes because the muscles get consumed in order to provide energy to the body. The immune system can be impaired as well. Muscle repair is inhibited and the work of breathing is increased.

Key Takeaways

- Exercising in low temperatures will shunt blood away from the skin, increasing the blood pressure.
- The main things that can happen with exposure to cold-weather training are frost nip, frostbite, and hypothermia.
- Exercising at high temperatures increases the risk of dehydration and heat-related illnesses.
- Hot yoga will increase the basal metabolic rate, decreasing the body mass index when practiced regularly.
- There are acute and chronic effects on the lungs, the cardiovascular system, and the metabolism at high altitudes, which begins at about 1500 meters elevation.

QUIZ

1. What most contributes to higher blood pressure when working out in cold temperatures?

    a. Higher cardiac output at low temperatures
    b. Decreased peripheral vascular resistance at low temperatures
    c. Increased need for pulmonary blood flow at low temperatures
    d. Increased shunting of blood away from the skin

    > Answer: d. In cold temperatures, there is increased shunting of blood away from the skin, which causes increased peripheral vascular resistance. There is more blood that needs to be pumped through a smaller effective blood volume, leading to an increase in blood pressure.

2. What is not a reason why muscle function is less effective at lower temperatures?

    a. The muscles have decreased blood flow in lower temperatures.
    b. Glucose energy is expended to maintain core body temperatures.
    c. Muscle fibers are stiffer at lower temperatures.
    d. There is decreased enzyme efficiency at lower temperatures.

    > Answer: c. Each of these is a reason why muscle function is less effective at lower temperatures. They are not, however, stiffer at low temperatures; they just feel that way because of decreased blood flow to them.

3. What is not an early sign of hypothermia in the exercising athlete?

    a. Confusion
    b. Shivering
    c. Numb extremities
    d. Poor dexterity

Answer: a. Confusion is a late sign of hypothermia, while shivering, numb extremities, and poor dexterity are all early signs of hypothermia, when the body temperature dips just two degrees below normal.

4. At what core temperature does the heart stop beating in the hypothermic athlete?

   a. 33 degrees Celsius
   b. 30 degrees Celsius
   c. 25 degrees Celsius
   d. 20 degrees Celsius

   Answer: d. At 20 degrees Celsius, the heart stops beating. This will lead to death if the individual does not get urgent treatment with warming aids and a heart-lung machine isn't used to manage circulation while the body warms up.

5. A relative lack of what electrolyte in muscle tissue is believed to account for heat cramps with exercise in hot weather?

   a. Potassium
   b. Hydrogen ion
   c. Sodium
   d. Calcium

   Answer: c. Hyponatremia or low sodium is believed to be the major cause of muscle cramps seen when an athlete is not well-hydrated during hot weather.

6. What is not a symptom of heat stroke?

   a. Confusion
   b. Sweating
   c. Dizziness
   d. Palpitations

Answer: b. Sweating is a typical sign of heat exhaustion but is not generally seen in heat stroke because the sweating mechanism is impaired. Instead there is dry skin, which further brings the body temperature up.

7. What is the preferred drink of choice during exercise in hot weather?
   a. Room temperature water
   b. Cold water
   c. Electrolyte solution
   d. Cool water

   Answer: d. Cool water is the recommended drink of choice for the athlete exercising in hot weather. Cold water is not going to absorb very well and electrolyte solution only adds calories that are unnecessary in the exercising athlete unless the workout is longer than ninety minutes.

8. What are the conditions used in the practice of Bikram or hot yoga?
   a. 90 degrees and 80 percent humidity
   b. 95 degrees and low humidity
   c. 105 degrees and 40 percent humidity
   d. 120 degrees and 20 percent humidity

   Answer: c. The set conditions for Bikram yoga are 105 degrees and 40 percent humidity, which is an environment that promotes sweating and an increase in heart rate during the exercise.

9. What will the relative effects be on aerobic and anaerobic performance in the athlete trying to perform at high altitudes?
   a. Both aerobic and anaerobic performance will be equally impaired.
   b. Anaerobic performance will be more adversely affected than aerobic performance.
   c. Aerobic performance will be more adversely affected than anaerobic performance.
   d. Aerobic performance will be impaired but not anaerobic performance.

Answer: d. Because lactic acid doesn't build up at maximal performances in high altitude anaerobic events, this will not be affected and may improve with decreased air resistance, depending on the event. The endurance events will be impaired because of impairment in VO2 max.

10. What happens to the hematocrit count and cardiac output after several weeks of living at high altitudes?

    a. The hematocrit decreases and the cardiac output decreases.
    b. The hematocrit increases and the cardiac output decreases.
    c. The hematocrit decreases and the cardiac output increases.
    d. The hematocrit increases and the cardiac output increases.

    Answer: b. The response to the low oxygen tension is to raise the hematocrit by increasing the erythropoietin level. The result is that the heart does not have to work as hard to pump oxygen around so the cardiac output decreases.

Chapter 7: Sports Training

The focus of this chapter is sports training. One of the goals of the sports physiologist is to determine the best exercise prescription for the athlete starting or changing their exercise program. When aiding a person in starting an exercise program, there are certain questions that must be asked prior to starting the program and specific ways to start these types of programs. Before, during, and after training, it is a good idea to determine the athlete's body mass index (BMI) and body composition in order to follow their progress. In addition, some will want to use various ergogenic aids in order to maximize their performance, so this is discussed in this chapter.

Starting an Exercise Program

Not every athlete can begin an exercise program without thinking first about their preexisting health status and the risks that come on with exercise. Some of this depends on the degree of exercise the athlete wants to engage in. Mild exercise will most likely help anyone, but intensive exercise can exact a toll on the cardiovascular, respiratory, or musculoskeletal systems, which is something that not everyone can handle.

Low-to-moderate exercise can be done by nearly anyone. It involves non-competitive sporting activity that starts slowly and progresses gradually so that the activity can comfortably be sustained for at least sixty minutes. These types of exercises include slow walking, gardening, and golf. Vigorous exercise is exercise of an intensity that the heart rate and breath rate increase for about twenty minutes before tiredness sets in.

Men over 45 and women over 55 years who have not been active but who anticipate vigorous activity should have a medical examination first. This is also true of anyone with two or more coronary artery disease risk factors. Things that indicate a need for a medical examination include:

- History of heart condition of any kind (including valvular heart disease, high blood pressure, structural heart disease, and coronary artery disease).

- Known chest pain, chest discomfort, or neck, shoulder, or jaw pain that comes on with exercise.
- History of irregular heartbeats or slow heartbeats with exercise.
- History of dizziness, syncope, poor balance, or falls for any reason.
- Known bone or joint disease, including undiagnosed joint pain.
- History of foot cuts or foot wounds that do not heal.
- Recent history of unexplained weight loss.
- Known lung disease like chronic obstructive pulmonary disease or asthma.

The benefits of exercise are many. Those who exercise have consistently low body mass indices, reduced risk of heart disease, and decreased risks for diabetes and cancer. Arthritic pain can be lessened with exercise and exercise is better for the treatment of depression than medications. Exercise can also strengthen bones.

The goal you should strive for is 150 minutes of moderate-intensity aerobic exercise per week. As mentioned before, the athlete should choose an activity they enjoy as part of their exercise program in order to maximize compliance over the long-term. Varying activities over the course of a week sometimes helps.

The program should start as low as is readily tolerated and increased gradually. Most of the time, aerobic exercise must be a minimum of 10 minutes at a time in order to be helpful. The intensity should also begin at levels easily tolerated and should increase to a greater intensity. Moderate intensity involves a rating of five to six on a scale up to 10. Examples include brisk walking, gardening, biking less than 10 miles per hour, and ballroom dancing. Vigorous activity involves at least seven on a scale up to 10. This would be things like tennis, lap swimming, race walking, running, jogging, or fast bicycling.

As we talked about in previous chapters, resistance training should be a part of an exercise program. At about twice a week, all major muscle groups should be strengthened by doing weight lifting or machine weights at 8-12 repetitions per exercise and as many sets as necessary to tire the major muscle groups.

Body Composition and Training

Body composition involves some type of measurement of how much fat and muscle the body is made of. There is more than one model that is used to determine body composition. The first is called the fat mass. Fat is a good storage form of energy, regulates body temperature, and protects the internal organs. It is impossible to have a zero percent body mass. In fact, anything less than four percent body mass is not considered to be healthy over the long-term.

The second model determines the fat-free mass which includes the bones, skeletal muscle, internal organs, and water. From the fat-free mass and fat mass, the body fat percentage can be deduced by taking the fat mass and dividing the total body weight.

Adults are more than 50 percent water, all the cells of the body (fat, muscle, blood, and organs) contain water and there is extracellular water in the blood and outside the cells. Much of the protein in the body is in the muscles, although all cells and organs have protein in them. Minerals can be found in the bloodstream and bones. Fat can be found between intraabdominal organs and surrounding the body beneath the skin.

Important things needed to know when understanding body composition include the following:

- Dry lean mass—this is the combination of the weight that can be seen in protein as well as the bone mineral component of the body. As you might expect, it does not include any water.
- Lean body mass—this is the combination of the dry lean mass plus the body water.
- Skeletal muscle mass—this is the mass of the skeletal muscles in the body; it is those muscles that allow for physical movement.

The body composition analysis is, in some cases, better than determining the body mass index or BMI, which will be discussed next. While the BMI analysis is simpler, it does not measure body fatness as much as a body composition analysis because it cannot tell the difference between fat and muscle mass even though a pound of muscle takes up much less space than a pound of fat.

Athletes with a high skeletal muscle mass and a low percent body fat will potentially have a high BMI but will not be fat by any stretch. In the same way, a person who is sedentary and who has a normal BMI may be what's called "skinny fat." They have lost muscle mass but have a high percent body fat, which isn't healthy. Even though they have a low body weight, they are still at risk for the health complications associated with obesity.

Methods of Determining Body Composition

There are several ways to determine the body composition, some of which are expensive and require a trained technician. Others are simpler and can be done at home. The four main methods of determining these numbers include the following:

1. **Skinfold caliper method**—this involves using skin calipers to measure how much skinfold can be grasped by the arms of the calipers. The big advantage to this method is that it is portable and very easy to use. Several sites on the body are measured in millimeters by pinching the fat in the device. It is somewhat user-dependent and just gives a measurement of the amount of body fat a person has. Mathematical formulas are used to determine the amount of body fat. It does not give a measurement of the muscle mass or other masses in the body.
2. **Hydrostatic weighing method**—this is one of the gold standards in body composition measurement. It is also referred to as underwater weighing. It can calculate the body fat percentage by weighing a person submerged on a special scale inside a pool. The person being weighed expels all possible air out of the lungs. The underwater weight is compared to the land weight. There are calculations that are used, along with the density of water, to determine the body fat percentage. While it is very precise, it can only measure the body fat percentage so that skeletal muscle mass, dry lean mass, and body water are

not included. In addition, it needs to be done in a special environment using special equipment.

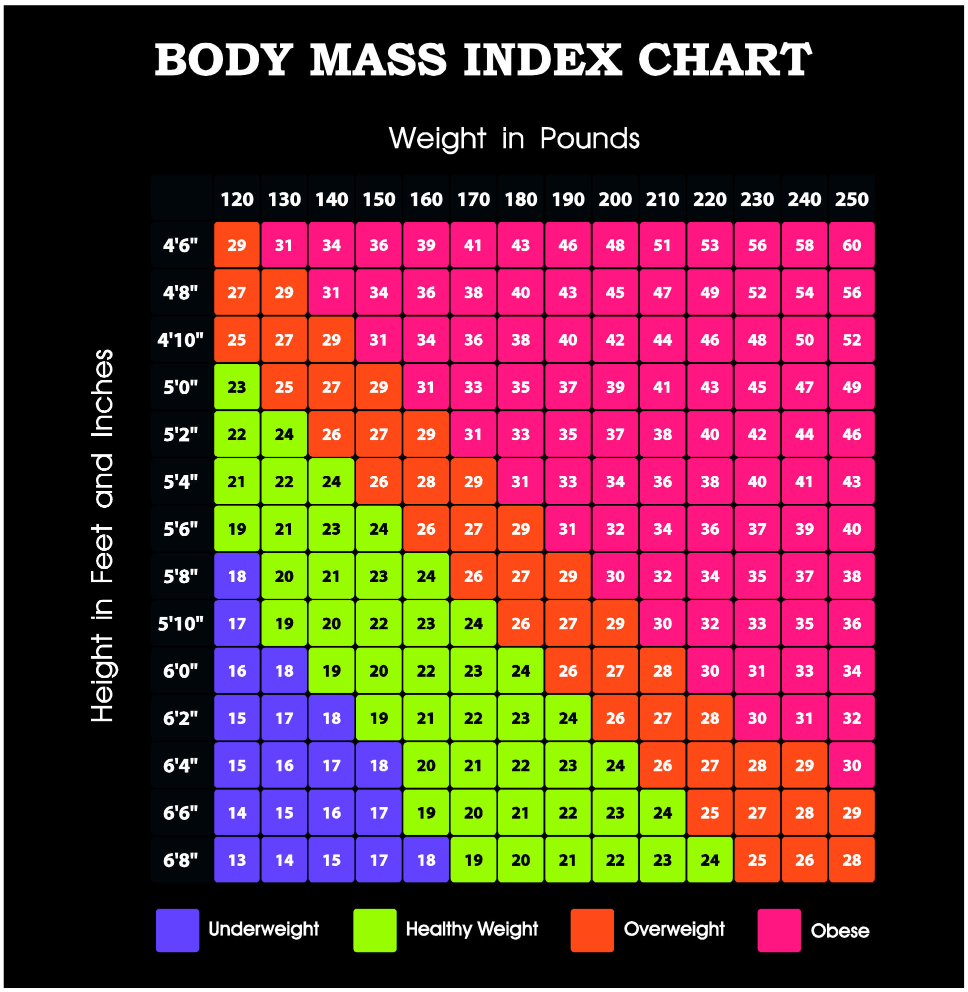
3. **Dual Energy X-ray Absorptiometry or DEXA scan**—this is another gold standard test for body composition. It was initially set up as a test for bone density but has expanded to measure body composition. It sends a small amount of x-ray energy through the body in order to measure the difference between the energy in and the energy out. It can accurately measure the fat mass, bone density, and soft lean mass in all segments of the body. There are places in the country that do this sort of measurement just for athletes. It is a good way of measuring the total body composition.

4. **Bioelectric impedance analysis or BIA**—this involves a test that uses a small electrical current sent into the body, measuring the opposition of that current or the "impedance" as it travels through the body's water. Calculations are used to determine the body composition. The biggest advantage is that it does not require another person. Most BIA devices are scales that weigh you and take a measurement over one or more frequencies of the impedance. The best devices can measure the impedance of the entire body or all the segments of the body but there are devices that measure leg impedance only and estimate the impedance of the rest of the body. A good device will determine the lean body mass, skeletal muscle mass, and body water weight as well as the body fat percentage.

Normal body fat percentages vary when it comes to men and women's values. A healthy body fat percentage for men is 10 to 15 percent, while for women, it is 18 to 25 percent. Anything higher than that will lead a person to increased health problems typically associated with obesity. A very "in shape" person will have a percent body fat of 8 to 10 percent in men and about 15 percent in women.

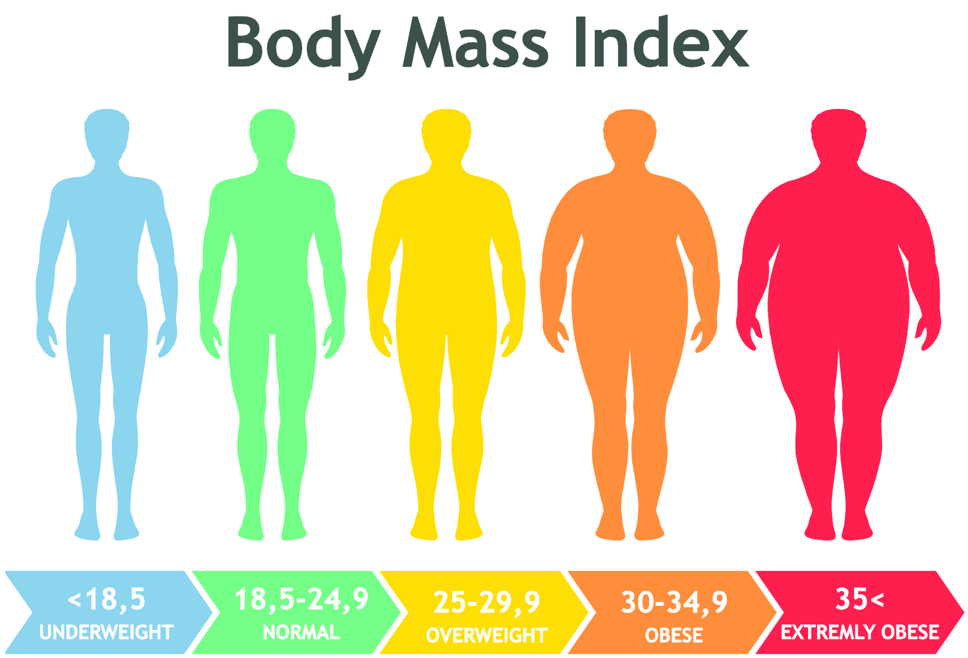
Body Mass Index

Doctors often have more access to the body mass index than the fat percentages. This is because it only depends on the person's weight and height. The units of BMI are kilograms per meter squared. While there are tables that determine what the BMI is, it can easily be calculated. It is the weight in kilograms divided by the height in meters squared. The same calculation can be had with pounds and inches as long as the whole thing is multiplied by 703. Figure 20 shows a chart that calculates the BMI:



	120	130	140	150	160	170	180	190	200	210	220	230	240	250
4'6"	29	31	34	36	39	41	43	46	48	51	53	56	58	60
4'8"	27	29	31	34	36	38	40	43	45	47	49	52	54	56
4'10"	25	27	29	31	34	36	38	40	42	44	46	48	50	52
5'0"	23	25	27	29	31	33	35	37	39	41	43	45	47	49
5'2"	22	24	26	27	29	31	33	35	37	38	40	42	44	46
5'4"	21	22	24	26	28	29	31	33	34	36	38	40	41	43
5'6"	19	21	23	24	26	27	29	31	32	34	36	37	39	40
5'8"	18	20	21	23	24	26	27	29	30	32	34	35	37	38
5'10"	17	19	20	22	23	24	26	27	29	30	32	33	35	36
6'0"	16	18	19	20	22	23	24	26	27	28	30	31	33	34
6'2"	15	17	18	19	21	22	23	24	26	27	28	30	31	32
6'4"	15	16	17	18	20	21	22	23	24	26	27	28	29	30
6'6"	14	15	16	17	19	20	21	22	23	24	25	27	28	29
6'8"	13	14	15	17	18	19	20	21	22	23	24	25	26	28

The commonly accepted BMI ranges are under-weight at less than 18.5, normal weight at 18.5 to 25, overweight at 25 to 30, and obese at over 30. Figure 21 shows these relationships:



The problem, as mentioned, with the BMI calculation is that it does not say what the body composition actually is. It will not take into account the fact that muscle is denser than fat and that this isn't completely scalable so that it depends more on the height than on the weight. The result is that tall people have a BMI that is uncharacteristically high compared to their actual body fat levels.

Still, there is plenty of research indicating that the BMI above the normal range is associated with a higher risk of several diseases, including the following:

- Stroke
- Sleep apnea
- Osteoarthritis
- Hypertension
- Gallbladder disease
- Type 2 diabetes

- Dyslipidemia
- Coronary heart disease
- Several cancers, including endometrial, colon, and breast cancer

Overweight and obese people, even those who have never smoked, have a 51 percent increase in overall mortality compared to individuals who have always been at a normal weight. It should be noted that the BMI is designed for sedentary people and is not a good measurement of weight in an individual who is actively training and is athletic. For these individuals, a body composition measurement is better.

Ergogenic Aids and Training

Ergogenic aids are substances that are consumed by the athlete presumably to enhance performance. About half of all people report taking some type of dietary supplement in the past, while some type of ergogenic aid has been used by 75 percent of all competing athletes. The number of bodybuilders who use an ergogenic aid is at 100 percent. More than 12 billion dollars per year are used to purchase these types of products in the US. They can be as dangerous as anabolic steroids and ephedrine or as safe as multivitamins. In this section, we will review the different products as to their safety and effectiveness.

Anabolic steroids are based on testosterone and have three mechanisms of action. The first is the reversal of the catabolic effects of glucocorticoids so that there is a positive nitrogen balance and protein synthesis. The second is an increase in skeletal muscle synthesis. The third is psychological as it produces a steroid-induced euphoria that allows for longer and harder training. There are many adverse effects, some of which are irreversible.

The major adverse effects of anabolic steroids include sexual side effects, such as scrotal pain, gynecomastia, decreased sperm production, and low or elevated libido. There are skin effects, such as acne, hirsutism, and edema. Psychological effects can include aggression, nervousness, and euphoria. More serious effects include hypertension and a risk of tendon rupture from dysplasia of the collagen fibers. These are available only with a prescription and are banned by many sports organizations.

Creatine is important in anaerobic metabolism, particularly in the first few seconds of exercise. Phosphocreatine helps in storing a high energy form of phosphate used to make ATP energy by the cell in intense exercise. Taking a creatine supplement will increase the stores of phosphocreatine by six to eight percent so that more ATP can be made. This supplement will also buffer lactic acid so that there is less muscle fatigue during exercise.

Research has shown that its supplementation will increase muscle mass and strength in both men and women. It does not appear to affect these things in older adults. It also doesn’t appear to affect the increase in sprinting times in athletes involved in these types of activities. The major side effect is weight gain. This is a legal product that is not banned by sports authorities.

Androstendione and dehydroepiandrosterone are precursors to both male and female steroids. The idea behind this is that they should physiologically increase testosterone synthesis. DHEA (dehydroepiandrosterone) has been studied as a replacement medication in older individuals, with increases in testosterone seen in women only. It doesn’t appear to affect muscle strength or performance in younger athletes. Even so, it is banned by many sports authorities, including the International Olympic Committee.

Caffeine will enhance skeletal and cardiac muscle contractility and will aid in fat metabolism, sparing glycogen stores in the muscles. It is also a central nervous system stimulant, which enhances concentration. It has been shown to increase endurance times in doses of at least 250 milligrams. At these doses, it will cause nervousness, restlessness, tremors, insomnia, and diuresis. Its use is legal; however, there are limits to the amount of this drug that can be in the bloodstream of competitive athletes as identified by several athletic authorities.

Some athletes will take caffeine and ephedrine together. Besides ephedrine, an herbal form of ephedrine called ma huang, phenylpropanolamine, and pseudoephedrine can be used for their stimulant properties. The goal of taking these along with caffeine is to increase metabolism, decrease appetite, and increase subjective energy. Adverse effects include nervousness, tachycardia, restlessness, hypertension, and arrhythmias. This has been linked to deaths when used together. For this reason, the use of ephedrine is banned by the International Olympic Committee (IOC).

Some athletes use protein and/or amino acid supplementation as these are the building blocks of muscle protein. Its use is designed to improve muscle growth and repair. Low protein intake cause fatigue and a negative nitrogen balance. Overall, most athletes need an increase in protein, with resistance-training athletes requiring more than double the recommended 0.8 grams per kilogram per day. The requirements for a novice athlete training with resistance training is about 1.6 grams per kilogram per day. Protein and amino acids are completely legal without any adverse effect.

Carbohydrates are a rapidly available source of energy and many athletes believe that taking carbs at the right time before and during athletic performance can enhance performance. In fact, carb loading (as it is referred to) is done for several days before an athletic event in order to prolong exercise endurance. There is no known benefit in those events lasting less than one hour because muscle glycogen is not depleted during this time.

Research has shown that eating a meal two to four hours does delay fatigue but this does not depend on the glycemic index of the foods taken in. On the other hand, some research suggests that drinking a carbohydrate-containing liquid will improve endurance of certain athletes. Drinking carbs after exercise can enhance glycogen re-synthesis after exercise. There are some adverse stomach effects in athletes who consume fructose. Of course, consuming carbs for exercise enhancement is completely legal.

Other ergogenic aids include the following:

- Alcohol—decreases anxiety
- Amphetamines—improve concentration, decrease fatigue, and decrease appetite but are illegal
- Antioxidants—decrease muscle breakdown but have no known benefits

- Lysine, arginine, and ornithine—stimulate the release of growth hormone but have no benefit
- Aspartates—increase the use of free fatty acids with mixed evidence of benefit
- Aspirin—decreases pain from muscle breakdown and fatigue
- Avena sativa—increases steroid production with limited benefit shown
- Bee pollen—increases strength and endurance but has no known benefit
- Beta blockers—decrease anxiety but are banned by the IOC
- Beta agonists—increase lean muscle mass but is banned by the IOC
- Blood doping—will increase aerobic activity but is dangerous and illegal
- Boron—increases endogenous steroid production but has no benefit even if legal
- Branched chain amino acids—decrease mental fatigue but have no apparent benefit
- Calcium—increases muscle contractility but has no benefit
- Carnitine—increases fat metabolism but has no known benefit
- Choline—increases endurance but has inconclusive benefits
- Chromium—increases lean muscle mass but has no known benefit unless deficient
- Chrysin—increases endogenous steroids with limited known benefits
- Cocaine—stimulates the central nervous system with mixed results; it is illegal
- Coenzyme Q10—increases aerobic capacity and speeds muscle repair but has no known benefit
- Diuretics—decrease total body mass but are banned and have limited benefit
- Erythropoietin—this will increase RBC production but is dangerous and illegal
- Fat supplements—increase endurance but have no known benefit
- Folic acid—increases aerobic capacity but has no known benefit

- GHB—stimulates growth hormone release and is illegal
- Ginseng—increases endurance and adds to muscle recovery but has no known benefit
- Glucosamine—decreases joint pain but has no known benefit
- Glutamine—enhances immunity and is legal
- Glycerol—enhances hydration and endurance; is legal
- HMB—decreases muscle breakdown and enhances recovery; is legal
- Human growth hormone—increases fat metabolism and enhances muscle growth; is illegal
- Inosine—enhances aerobic activity but has no known benefit
- Iron—increases aerobic capacity but has no known benefit; is legal
- Leucine—an amino acid that spares muscle glycogen stores but has no known effect
- Magnesium—enhances muscle growth but has no benefit
- Marijuana—decreases anxiety but can have negative effects; is illegal
- Narcotics—suppresses pain and anxiety but can have negative effects and is illegal
- Niacin—increases endurance and energy but has no known benefit
- Oxygen—increases aerobic capacity but has no known benefit; is legal
- Phosphates—increases ATP production but has no known benefit; is legal
- Phytosterols—stimulates release of endogenous steroids and growth hormone but has no benefit
- Pycnogenol—increases antioxidant levels and enhances recovery; seems to be beneficial
- Pyruvate—increases lean body mass but has limited benefit

- Selenium—enhances antioxidant functions but has no benefit
- Sodium bicarbonate—buffers lactic acid production and seems to have benefit; is legal
- D-ribose—increases cellular ATP and muscle power but has not been found to be helpful
- Tribulus terrestris—increases endogenous steroid production but has no benefit
- Tryptophan—decreases pain perception but has no benefit in trained athletes
- Vanadyl sulfate—increases glycogen synthesis and enhance muscle recovery; has no benefit
- Yohimbine—increases endogenous steroids but has no benefit
- Zinc—enhances muscle growth to increase aerobic capacity; has no known benefit

While many athletes or potential athletes want to start some of these supplements in order to advance their athletic performance, they need to know that most do not benefit performance to any particular degree and at higher doses, many have adverse side effects.

Exercise Prescriptions

Exercise prescriptions involve a plan of fitness-related activities based on the specific needs of the client. The goal is to begin to integrate exercise principles and behavioral techniques that help the client achieve a particular exercise or health goal. The components of the exercise prescription include the following:

- Specific type of activity or exercise recommended based on the client's interests and abilities.
- Specific workloads, such as joules to be expended or speed of walking
- Duration and frequency of the activity or exercise session
- Recommended targets regarding rate of perceived exertion and target heart rate

- Precautions to take into account, such as heart disease and arthritis restrictions

As a trainer or health professional, it should be clear that there are significant benefits to physical activity. This applies to individuals of all ages and both genders. Exercise prescriptions should be considered starting in childhood in order to begin a program of regular exercise that can last a lifetime. The primary activity that should be suggested is aerobic activity—that which increases the breath rate and heart rate. This will have the greatest effect in prolonging life and enhancing health. This is followed by resistance training, which should be done two to three times per week.

In some cases, the VO2 max can be done at the time of starting a program of aerobics and periodically during the programming. Physical activity levels are associated with the individual's VO2 max with highly active individuals having a greater VO2 max than sedentary individuals. An exercise stress test can be considered in an individual who has a risk of heart disease as it can predict ischemia of the heart with exercise.

When making exercise recommendations, it is important to recognize what a MET is when it comes to exercise. Many workout machines will have the number of METs listed during the workout. MET stands for metabolic equivalent. It is an estimate of the number of calories burned during a particular physical activity. The more oxygen is burned during exercise, the more calories are burned. It takes five calories of energy to consume a liter of oxygen. The more liters of oxygen consumed, the more calories burned in the aerobic activity.

One MET is the individual's resting metabolic rate, which is about 3.5 milliliters of oxygen per kilogram of bodyweight per minute. A three MET activity uses three times as much activity as is consumed at rest. There are assigned MET values for almost any type of activity with things like an eight-minute mile using about 11 METs of activity. The MET level is in the units of kcal/kg/hour.

As mentioned, the focus of the exercise prescription should be on aerobic activity. Other activities that can be recommended include anaerobic exercise (like sprinting), isotonic exercise (like weight lifting), and resistance exercise.

There are specific exercise prescriptions for different populations. For the elderly, you need to know that the maximum ventilation-perfusion match for the lungs drops 5 to 15 percent per decade between the ages of 20 and 80 years. Exercise over a lifetime improves this VQ match, further identifying exercise as beneficial for the aging population. Muscle strength and joint flexibility are also enhanced with regular exercise.

The aging population gets partial relief from the use of resistance training alone, which will improve carbohydrate metabolism by maintaining muscle mass and basal metabolic rate. It is also safe and beneficial for this population in improving quality of life and overall flexibility. Those with heart disease should refrain from heavy lifting and certain isometric activities; however, dynamic strength training is safe.

People with lung disease should have low workloads and shorter durations of activity. Frequent intervals of training are better than longer durations and shorter intervals. In some cases, supplemental oxygen might be necessary. Even so, they should not avoid exercise entirely.

Diabetics should start slowly and work up to longer durations as tolerated. Exercises that are appropriate are aqua-aerobics, walking, cycling, jogging, and swimming. Blood sugars should be monitored before, during, and after physical activity with adjustments in eating and insulin made according to the level of activity and the diabetic's disease state.

Obese individuals are at a greater risk of orthopedic stresses and joint injuries. They may need to start with floor exercises, water aerobics, and swimming classes. High-impact aerobic activity should be avoided as long as the person remains obese. Duration of the exercise should be as tolerated. Exercise should be done before eating in the morning in order to mobilize fat through lipolysis.

Exercise remains a healthy activity during pregnancy for the mother and fetus. There is limited weight gain and fat retention if exercising during pregnancy and labor is shorter with faster recovery. Pregnancy-related hypertensive disorders seem to be decreased with activity during early pregnancy that continues throughout the pregnancy. If at all possible, the pre-pregnancy levels of exercise should be maintained throughout the pregnancy as long as safety isn't a concern. The healthy woman should be allowed to start an exercise program for the first time during pregnancy.

Those with osteoporosis should consider starting an exercise program in order to begin strengthening muscle and bone. Exercise can also reduce the risk of falling and sustaining a fracture by enhancing balance. It can be used by those women who are also on medications that enhance bone density and strength. In fact, using things like exercise, diet, medications, and calcium supplementation together are more effective than any one of these modalities alone.

For those with osteoporosis, the exercise prescription should involve some type of weight-bearing exercise along with resistance training. Walking or stationary cycling are most recommended along with some type of weight lifting or other strength training, such as weight machines. The weight should start slowly and increase as the weight training becomes easier.

KEY TAKEAWAYS

- Certain individuals should have a medical evaluation before starting an exercise program.
- There are different ways to determine body fat composition that can be used before, during, and after exercise in order to follow the progress of the exercise program.
- The body mass index is widely used to determine those individuals who are healthy or who might have problems with health issues because of obesity.
- Ergogenic aids are intended to enhance athletic performance. Some do not help, while others are considered illegal.
- The exercise prescription is given to various persons in an attempt to find a tailored program geared toward starting and maintaining a fitness program.

QUIZ

1. Who most likely does not need a medical exam before starting an exercise program?

    a. A person with hypertension
    b. A person with chest pressure with activity
    c. A person with asthma
    d. A person with recent weight gain

    > Answer: d. Individuals with weight gain generally do not need to get a medical exam before starting an exercise program; however, those with the other problems do need an exam.

2. At what age should a sedentary man have a medical evaluation before starting a vigorous exercise program?

    a. 35
    b. 45
    c. 55
    d. 65

    > Answer: b. At age 45 years, a man who is sedentary but is anticipating starting a vigorous exercise program should have a medical evaluation.

3. Which body composition measurement involves the use of x-ray energy to determine body composition?

    a. Skinfold calipers
    b. Hydrostatic testing
    c. DEXA scan
    d. Bioelectric impedance testing

    > Answer: c. The DEXA scan makes use of x-ray energy in order to measure the body composition of an individual, being able to measure more than just percent body fat.

4. What is the upper limit of normal for percent body fat in men?

    a. 5 percent
    b. 15 percent
    c. 25 percent
    d. 35 percent

    Answer: b. The upper limit of normal for body fat in men is 15 percent. Higher than this and the body fat percentage will indicate a risk for obesity-related problems.

5. What is the BMI above which the person is considered to be obese?

    a. 25
    b. 30
    c. 35
    d. 40

    Answer: b. A body mass index of greater than 30 in the man or woman is considered obese, with a number greater than 35 is considered morbidly obese. Normal body mass index is 18.5 to 25.

6. For which type of person is the BMI most designed for?

    a. The bodybuilder
    b. The tall person
    c. The aerobic athlete
    d. The sedentary person

    Answer: d. The BMI is not intended to be accurate for body builders, very tall individuals, or even an aerobic athlete. It is intended for people who are entirely sedentary and can best predict the person's health risk based on where they fall in the measurement.

7. You are recommending protein intake for a resistance-training athlete. What do you do with regard to recommending their protein intake?
    a. Recommend the usual 0.8 grams per kilogram per day as increased protein makes no difference
    b. Recommend double the usual intake of protein
    c. Recommend triple the usual intake of protein
    d. Recommend quadruple the usual intake of protein

        Answer: b. In most resistance-training athletes, it is sufficient to double the protein intake. The biggest danger of taking in more is that it is associated with a higher caloric and fat intake, which would be the major adverse effect.

8. What is true of taking carbohydrates as part of exercise performance?
    a. It enhances performance in short-term activities.
    b. It increases glucose metabolism during exercise.
    c. Fructose is preferable to glucose as a carbohydrate.
    d. Taken after exercise, it will enhance glycogen production.

        Answer: d. While a meal will enhance endurance, it doesn't have to be carbohydrates, which don't help in short-term activities. They don't increase glucose metabolism to any extent. Fructose can lead to stomach upset. Taken after exercise, glucose supplementation will enhance glycogen re-synthesis.

9. What is the number of METs consumed at rest?
    a. one MET
    b. two METs
    c. three METs
    d. four METs

        Answer: a. One MET is the amount of energy consumed at rest in kcal/kg/hour. Most physical activities burn more METs than that. Each

MET will double the amount of energy spent in the activity compared to resting energy expenditure.

10. In doing an exercise prescription, what is the type of exercise that should be at the forefront of this type of prescription?

    a. Resistance exercise
    b. Isotonic exercise
    c. Aerobic exercise
    d. Anabolic exercise

    Answer: c. The focus of an exercise prescription should be on aerobic exercise versus any other type of exercise as it affords the greatest protection against long-term diseases.

Chapter 8: Nutrition in Training

This chapter covers the basics of the nutrition of carbohydrates, protein, and dietary fats. There is much misinformation about these different types of foods and the role they play in athletics. There are many fat diets out there and many athletes have specific ideas about what foods they should consume or avoid before, during, and after training. This chapter offers solid information about the different types of macronutrients in the diet and how they are used in athletics as fuel sources for different types of training.

Carbohydrates

Carbohydrates represent one of the three main macronutrients in the diet, with the other two being protein and dietary fat. Carbohydrates have four calories per gram of carbohydrate taken in. The same holds true of using carbohydrates as fuel. The athlete will get four calories of energy out of every gram of carbohydrates stored in the body.

Not all carbohydrates are the same. They differ in how they are absorbed and their chemical structure. Simple carbohydrates are things like glucose, fructose, and galactose (which are called monosaccharides because they consist of just one sugar subunit), and lactose, maltose, and sucrose (which are disaccharides, consisting of two monosaccharides together). Sucrose is the disaccharide found in table sugar, while lactose is what's commonly known as "milk sugar."

Complex sugars have many associated sugar chains; the main one is starch or amylum, consisting of many glucose chains together. Interestingly, cellulose is a complex sugar found in plants that cannot be digested by humans. Chitin is found in the cell wall of insects and fungi (like mushrooms) that is also not digestible. Other forms of fiber include hemicellulose and lignins.

Simple sugars tend to increase the blood sugar quickly and may be used by athletes who are actively exercising and seeking a quick source of fuel. On the other hand, complex carbohydrates are favored by diabetics who do not want wide swings in blood sugar and by athletes who want to store carbohydrates for use by muscle and liver glycogen—the two major places where sugar is stored in the body.

The recommended intake of carbohydrates varies according to activity level and gender. For women, the recommended simple intake is about 50 grams daily, while for men, the recommended carbohydrate intake is 70 grams per day. The dietary guidelines for carbohydrates (simple and complex carbohydrates) indicate that carbs should provide 45 to 65 percent of your daily calorie intake. So, if an individual eats a 2000-calorie diet, they should plan on about 225 to 325 grams of carbs per day. But if weight loss is desired, a person will get much faster results eating around 50 to 150 grams of carbs per day. For athletes, the carbohydrate intake is 6-10 grams of carbohydrate per kilogram of body weight.

What this means is that most of the carbohydrate intake should come in the form of complex carbohydrates rather than simple carbohydrates. While complex carbs can be found in things like white bread, pastries, and cakes, most nutritionists recommend whole grain foods and starch-containing vegetables, which are more slowly absorbed and contain a lot of fiber. Fiber is healthy for the GI tract as it prevents constipation and holds onto sugar so it can be more slowly absorbed by the GI tract.

Biochemically, carbohydrates contain carbon, hydrogen, and oxygen only. They do not contain nitrogen so they are not able to build protein without something in the diet that contains nitrogen. Many people trying to lose weight believe that carbohydrates should be restricted, while others believe that carbs are healthy. As you can see, carbs are recommended to make up the majority of the diet (45 to 65 percent).

The main function of carbohydrates is to provide the body with an energy source. Carbohydrates do make up components of the cell membrane, of receptors, and of enzymes but this is not what carbohydrates are really intended to do. Almost all of the carbs that get digested are turned into glucose before even entering the bloodstream and all metabolism of carbohydrates is funneled through glucose. Glycolysis, which leads to both anaerobic and aerobic metabolism, involves glucose.

Glucose is what leads to ATP production and ATP is what fuels the entirety of energy in the body. While amino acids and fatty acids can be metabolized, these are not the main source of energy in the cells of the body. Glucose is what athletes need for rapid energy and the ATP necessary for fueling muscles. This is why glycogen is stored in the muscles. It is necessary for the contraction of the muscles that glycogen be readily available.

The liver stores roughly 100 grams of glycogen that can be released into the bloodstream in order to provide energy to all cells of the body. Only muscles, however, can use muscle glycogen. Muscle glycogen is used during high-intensity exercise. In actuality, there is more glycogen in muscles than is in the liver—at 500 grams total.

When glucose or glycogen isn't available, the body will break down protein in order to have nutrients. This isn't, however, what the body prefers to do. Glucose is the preferred energy source in the body. Without it, the cells will catabolize themselves; this includes muscle cells so, if not enough carbs are taken in, the loss of muscle mass leads to ill health and a greater risk of death from all causes. Glucose is the only energy source for the brain cells so some carbs are necessary for brain function.

As mentioned, dietary fiber is the kind of carbohydrate that does not get digested by the human body. It should be noted that, in other species, the indigestible fiber forms in humans may be digested. There are two main fiber types: insoluble and soluble fiber. Soluble fiber is found inside some fruits, in legumes, in certain vegetables, and in oats and oatmeal. It takes in water and forms a gel-like substance in the lumen of the bowel. This will increase stool bulk and will soften the stool. It also holds onto sugars, making them less able to be absorbed by the GI tract.

Insoluble fiber helps in the alleviation of constipation by increasing the bulk of stools and by helping the food move more quickly through the digestive tract. It may also prevent many digestive diseases, such as colon cancer and diverticulosis, because it hastens passage of food through the colon. This type of fiber can be found in the skins and seeds of fruits and vegetables as well as in whole grains.

Eating large amounts of refined carbohydrates or refined sugars are not heart-healthy and will increase the risk of diabetes. This is where the eating of fiber will be helpful. Soluble fiber will bind to bile acids so they aren't absorbed by the body as much. Bile acids are made from cholesterol; in order to make more bile acids, the liver uses cholesterol that would otherwise go to the bloodstream. This will lower LDL or "bad" cholesterol, reducing the risk of heart disease. Fiber is good for diabetics because it lowers overall blood sugars.

With very low blood sugars or in times of starvation, the brain can use ketone bodies or ketones in order to have something for metabolism. Ketones come from the breakdown of fatty acids, particularly when carbs are unavailable. The lack of carbs leads to what's called ketosis, which serves to protect muscle from being broken down during times of starvation. While ketones become the primary supply of fuel for starving brain cells, the brain still needs glucose for as much as one-third of the fuel necessary to run it. This glucose comes from muscle breakdown.

Glycemic Index

Some foods will raise the blood sugar quickly while others will allow for a gradual increase in blood sugar. This becomes important for diabetics and for athletes who may want, under some circumstances, to have a rapid source of sugar, while under other circumstances, to have a sugar or carb that is slower in onset. The glycemic index is a way to understand which carbs are rapidly-acting and which carbs are slow-acting.

The glycemic index or GI is an arbitrary number without units. The range for the glycemic index is from 1 to 100, with the lower number being less impactful on the blood sugar after meals or any type of carb intake. A low glycemic index is anything 55 or less, while a medium glycemic index is 56 to 69. Any glycemic index greater than 70 is considered high. Foods that are close to that found in nature will tend to have lower glycemic indices than foods that are refined or processed.

The glycemic index can change with the processing of the food. When fat, acids (such as vinegar or lemon juice), and fiber are added to a food, they will decrease the glycemic index. The longer starches are cooked, the greater is the glycemic index. Fruits that ripen will have a higher glycemic index and eating foods with a lower glycemic index together with high-glycemic index foods will lower the overall glycemic index.

The glycemic index isn't the only thing necessary for making carbohydrate food choices. Some food will have a low glycemic index but will have no nutritional value. The total calories, vitamins, and mineral content of foods are also important in determining which foods to eat. An example is potato chips, which have no nutritional value but have the same glycemic index as green peas, which have a high glycemic index.

The glycemic load also affects the blood sugar. It accounts for the quantity and quality of food that is eaten. Any glycemic load less than ten is considered low, while a glycemic load greater than 20 is considered high. To eat a lower glycemic load, stick to foods that have a low glycemic index and not much refined sugar. Fruits, vegetables, nuts, and whole grains all have a low glycemic index.

Carbohydrate Loading

Carbohydrate loading or “carb-loading” is a specific strategy used by athletes to maximize performance in endurance events by increasing the glycogen stored in muscles. Remember, glycogen is where most muscle fuel comes from. The body needs this existing energy source for fuel in endurance activities. This makes carb loading beneficial for athletes who engage in intense endurance sporting activities. By scaling back physical activities and carb loading, the athlete can prepare for a specific event.

Carb loading is mainly for activities requiring sustained activity for longer than 90 minutes. The body’s muscle has enough stored glycogen for about 90 minutes of activity—after which fatigue can set in and performance can suffer. It takes about a week for carb loading to be effective.

It is recommended that one to three days before the event, carbs intake should increase to 8 to 12 grams of carbohydrates per kilogram of body weight. High fat foods should be restricted to compensate for carb-rich foods to be eaten. Training should be scaled back during this time so as to increase the amount of muscle glycogen. For general training, fewer carbs can be ingested (in the range of five to seven grams per kilogram per day). Endurance athletes may ingest up to 12 grams per kilogram per day before an event.

Even with carb loading, the athlete may need to replenish the carbohydrate levels during an endurance event in order to maintain blood sugar levels. This is done by taking in 30 to 60 grams of a rapidly-acting sugar every hour or two during the event. This can be done by eating or drinking sports drinks, carbohydrate bars, carb-containing gels, or hard candy. Carbs should be taken in after an event in order to replenish the glycogen stores.

The major risk of carb loading is digestive discomfort. High fiber foods might need to be decreased or avoided because of abdominal bloating. Things like broccoli, bran, and beans can cause gas and loose stools so these should be avoided. Diabetic athletes may need to avoid high glycemic index foods so as to avoid having high blood sugars.

PROTEIN

Protein is another macronutrient in the diet. It is found in every cell and is what makes up a great portion of the skin, hair, muscle, and bone. It also makes up the structure of the enzymes that drive the chemical reactions in the body. There are about 10,000 different proteins that make up the proteins in the body.

All protein is made up of amino acids. There are twenty different amino acids that make up the different proteins, of which nine are essential amino acids. They are called "essential" because they are derived from the food that is eaten and cannot be synthesized by the human body. Different animals will have different essential amino acids.

The recommended protein intake for the average person is about 0.8 grams of protein per kilogram of body weight daily. Endurance athletes need slightly more protein at 1.2 to 1.4 grams of protein per kilogram of body weight per day. Ultra-endurance athletes need even more protein. Strength-training athletes should take in 1.2 to 1.7 grams per kilogram per day. Intake of greater than two grams per kilogram are not recommended, regardless of the activity of the athlete. Things like casein, whey, or soy protein can each be used for the synthesis, repair, and maintenance of the muscle proteins. This adds up to about 10 to 35 percent of calories each day.

Protein insufficiency is a worldwide problem, with protein and protein-calorie malnutrition a common problem in children who have trouble getting enough food. While marasmus is the name given to an overall calorie deficiency, kwashiorkor is the name for protein malnutrition. Children with kwashiorkor will have distended bellies from fluid that builds up in the abdomen from a lack of protein in the bloodstream to draw it back out.

The protein that one eats is important. Certain proteins may seem healthy but contain great amounts of salt (sodium) or saturated fat, which isn't healthy for the athlete. Eating a steak will increase protein intake but will also increase the saturated fat in the diet. Ham will increase the sodium. Salmon is, on the other hand, high in protein, low in saturated fat, and low in salt. It also has omega-3 fatty acids, which are heart-healthy. Lentils have no salt, no sodium, and contain protein and fiber. It's these differences that make protein healthy or not healthy.

Research shows that eating red meat increases the risk of heart attacks and strokes, while replacing red meat with things like poultry, fish, nuts, soy, and beans will enhance the protein intake without the risks. There is fat in the protein sources that come from plant sources but this is considered "healthy fat" versus "unhealthy fat." There is no cholesterol in plant sources, which is considered an unhealthy fat. Processed red meat is the worst type of meat to consume, increasing the risk of heart disease by 20 percent if just a hot dog or two strips of bacon are eaten per day on a regular basis.

How meat is cooked may also change the risk of type 2 diabetes. Cooking meat at a high temperature will increase the diabetes risk. It will also lead to greater weight gain versus low-temperature cooking. Low carb diets in general do not cause type 2 diabetes but those that are high in animal protein and fat still will increase the risk of type 2 diabetes.

When it comes to cancer risk, red meat and processed red meat increase the risk of all types of cancer deaths. Protein especially increases the risk of colorectal cancer, stomach cancer, pancreatic cancer, and prostate cancer. Grilled meats have been found to contain cancer-causing carcinogens.

While there are some benefits over the short-term to eating a paleo diet (high in protein and low in carbs), avoiding healthy carbs leads to missing out on the other nutrients (vitamins, minerals, and fiber) that can be found when eating whole grains and fruits. Certain proteins in food can also lead to allergies, such as those seen in nut, peanut, milk, soybean, and gluten allergies.

While protein is healthy for the athlete, muscle growth can occur only when diet and exercise happen at the same time. There is no advantage to protein-loading in the athlete. High-quality protein eaten after exercise (within two hours after exercise) will enhance muscle repair and growth. This can be consumed along with carbohydrates in order to have glycogen rebuilt and muscle repair after exercise.

Power athletes need greater amounts of protein than other athletes. While protein powders are convenient, these are not necessarily recommended for the average athlete as the amount of protein necessary for athletes can easily be obtained through a normal balanced diet. They can be used right after training or athletic events for muscle repair when the athlete has no time for a normal meal.

Fats

Fats are important to the diet. Low-fat diets are just as unhealthy as any other extreme diet. Fats represent the third macronutrient in the athlete's diet. The goal in eating fat in the diet is to have a larger amount of healthy fat versus unhealthy fat. Unlike some amino acids, fats are easily made by the human body whenever there are excess calories in the diet. Another reason why fat is essential to the diet is because certain vitamins require fat in order to be taken up by the diet.

Unlike protein and carbs, which have four calories per gram of the macronutrient, fats contain nine calories per gram of the macronutrient. This makes fats more "fattening" than other macronutrients. This is why fat intake needs to be balanced with other types of foods in the diet. Again, the goal is to eat as much healthy fat and avoid unhealthy fat.

The two unhealthiest fats are saturated and trans fats. Saturated fats come from eating red meat, full-fat dairy products, and poultry. These will raise the total cholesterol levels, which increases the risk of heart disease. Trans fats are the unhealthiest fats to consume. These come from the partial hydrogenation of oils and are used in highly processed foods in order to preserve foods for longer. They also raise the risk of heart disease. Trans and saturated fats are solid at room temperature.

Monounsaturated fatty acids, polyunsaturated fatty acids, and omega-3 fatty acids are healthier fats. Monounsaturated fatty acids will improve blood cholesterol levels and can decrease the risk of cardiovascular disease. Polyunsaturated fatty acids are found in plant-based oils and are even healthier than monounsaturated fatty acids. Omega-3 fatty acids are a type of polyunsaturated fatty acid that is found in fatty fish and some plants (like ground flaxseeds, certain vegetable oils, and nuts). These omega-3 fatty acids have been found to improve the risk of heart disease. These fats will be liquid at room temperature.

The recommendations for fat intake include avoiding trans fats altogether as they are solely a product of preserved food. The average person should have less than 10 percent of calories as saturated fat in the diet. Fat intake for an athlete should range between 20 and 35 percent of total daily calories (split between unsaturated, monounsaturated, and polyunsaturated fats).

Athletes need to remember that fat is the primary fuel used for low to moderate-intensity exercise. Carbs are stored in small amounts in the body compared to the amount of fat stored in the body. Triathletes and other athletes in endurance sports will fatigue easily if they have to rely solely on the carbohydrates stored in the body. On the other hand, the amount of fat that can be stored by the body is nearly unlimited. These are found as triglycerides to be stored in fat cells.

The lesson for the athlete is that eating fat is important and will both increase vitamin absorption and provide fuel for endurance exercises but it will not affect overall performance. Endurance athletes should not attempt a low-fat diet as this will lead to low stores of necessary fat but actually loading with fat as is done with carb-loading does not really enhance performance before an athletic event.

Key Takeaways

- The three main macronutrients are carbohydrates, protein, and fats. Vitamins and minerals are micronutrients—taken in very small quantities.
- Carbohydrates can be simple carbohydrates or complex carbohydrates. Complex carbs have lower glycemic indices and have advantages over simple carbohydrates.
- Simple carbohydrates provide the best resource during an event or exercise as they provide quick energy.
- Proteins are made from amino acids. They make up the majority of the structural components of the body as well as the enzymes in the body.
- Both protein and carbs should be eaten shortly after exercising so as to rebuild glycogen stores and help repair muscle.
- Fats can come in healthy and unhealthy forms, with fats that are liquid at room temperature being healthier than fats that are solid at room temperature.
- Trans fats should not be consumed in any form as these increase the risk of heart disease and are a product of food processing.

QUIZ

1. How many calories can be found in a gram of carbohydrates?

    a. two
    b. four
    c. six
    d. nine

    Answer: b. There are four calories per gram of carbohydrates making for the same number of calories per gram of protein and less than half of the calories per gram of dietary fat.

2. Which of the following is not a simple monosaccharide sugar?

    a. Lactose
    b. Glucose
    c. Galactose
    d. Fructose

    Answer: a. Lactose is the two-monosaccharide chain that is seen in milk. The others are easily-absorbable simple monosaccharide sugars that are easily absorbed by the athlete. Of these, glucose is the preferred monosaccharide as this is directly metabolized by the cells.

3. What element is not found in carbohydrates?

    a. Nitrogen
    b. Carbon
    c. Hydrogen
    d. Oxygen

    Answer: a. The chemical structure for carbohydrates is $C6H12O6$, which involves just carbon, hydrogen, and oxygen. It does not contain nitrogen at all, meaning that it cannot make proteins without some type of nitrogen-containing substance in the food.

4. Which is the main circulating monosaccharide in the bloodstream?
    a. Sucrose
    b. Galactose
    c. Fructose
    d. Glucose

    Answer: d. Glucose is the main circulating form of sugar, being the monosaccharide that is found in the bloodstream and the cells. All monosaccharide metabolism is funneled through glucose as it is the main sugar going through carbohydrate metabolism.

5. What is not a benefit of eating more fiber?
    a. It will reduce the risk of kidney disease.
    b. It can reduce the risk of heart disease.
    c. It will lower cholesterol levels.
    d. It will lower the risk of diverticular disease.

    Answer: a. Fiber in the diet can do many things, including decrease the risks for diabetes, high cholesterol, colon cancer, and heart disease. It does not, however, reduce the risk of kidney disease.

6. During times of starvation, where does the majority of brain energy come from?
    a. Glucose
    b. Cholesterol
    c. Ketones
    d. Amino acids

    Answer: c. Ketones provide two-thirds of the energy necessary for brain cells during times of starvation. Even so, muscles will be catabolized in order to make some glucose for brain functioning, even in low-carb diets.

7. About how many amino acids make up the protein in the human body?

    a. 9
    b. 20
    c. 35
    d. 100

    Answer: b. About 20 amino acids put together in different ways go into the making of the protein in the body. Of these, nine of them are considered essential amino acids because they cannot be synthesized by the body and must be taken in through the food.

8. What is the maximum amount of protein necessary to be taken in by the athlete who is strength training?

    a. 0.8 grams per kilogram daily
    b. 1.2 grams per kilogram daily
    c. 2 grams per kilogram daily
    d. 3 grams per kilogram daily

    Answer: c. It is not safe to consume greater than two grams per kilogram per day because it can stress the liver and kidneys. The average person should take in 0.8 grams per kilogram per day.

9. Which type of fat is considered the least healthy for the athlete to consume?

    a. Trans fats
    b. Monounsaturated fats
    c. Omega-3 fatty acids
    d. Saturated fats

    Answer: a. Trans fats are the least healthy of all of the fats because they are solid at room temperature and raise the total and LDL-cholesterol levels, making them at the greatest risk of causing heart disease.

10. What is not a good source of omega-3 fatty acids?

    a. Fatty fish
    b. Nuts
    c. Flaxseed oil
    d. Butter

        Answer: d. Each of these is a good source of omega-3 fatty acids except for butter, which is solid at room temperature and is high in saturated fat.

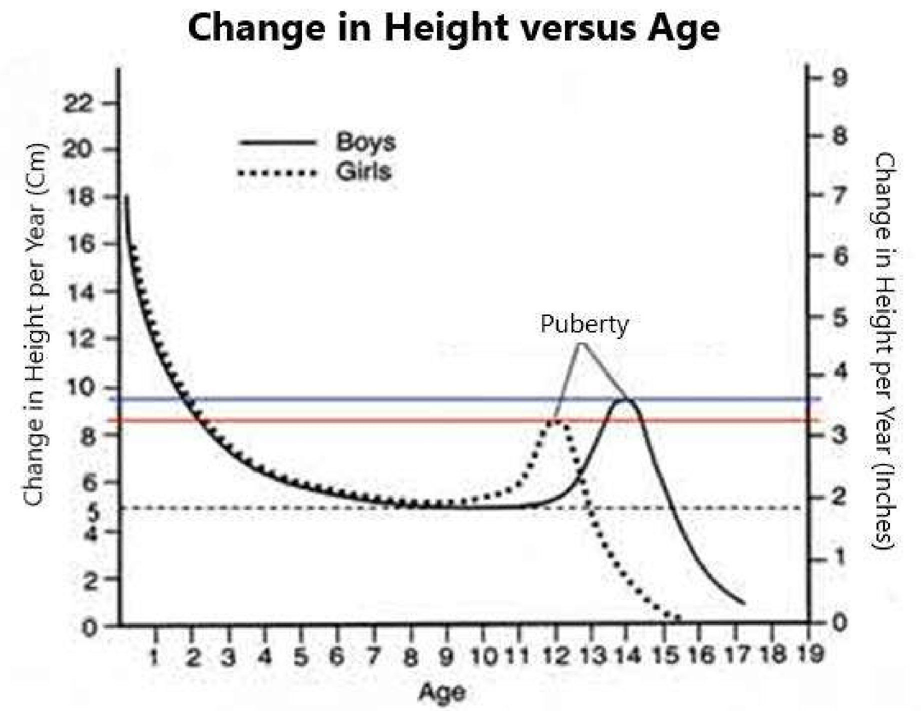
Chapter 9: Age and Gender Considerations in Training

This chapter focuses on age and gender considerations in training and exercise. Children often start athletics at an early age, thus developmental considerations must be included in their training and exercise programs. Exercise clearly benefits children of all ages but their exercise programming must be weighed against their developmental issues. When it comes to exercise, much of the emphasis is placed on the male athlete so this chapter deals with the female athlete and her unique issues and concerns. The problems, challenges, and advantages related to being athletic as an older adult are also discussed.

Athletics in Children

Children benefit from starting athletics and exercise from an early age. Childhood exercise is clearly linked to reductions in obesity and in the establishment of healthy activities later in life. As children are physically developing throughout their early lifetime, they will have different capabilities and adaptations to exercise. Because of this, programs designed for young athletes should not simply be scaled-down versions of those training programs designed for adults.

Children grow initially at a rate of about five inches per year for the first two years of their life. Growth continually happens at a rate of about 2.5 inches per year until puberty, which begins at the age of 11 or so in girls and at about age 13 for boys. This is when a growth spurt happens. Figure 22 shows the growth rates of children as they age:



As you can see, the pubertal growth spurt lasts about two years and, along with this, there are sexual developmental changes occurring in both genders. In males, the voice deepens, and in girls, menstruation occurs. The growth of pubic hair and the development of sexual organs occurs in both girls and boys. When the epiphyseal plates or growth plates of children fuse, the growth rate ceases. These changes occur between the ages of 12 and 15 in girls and between 14 and 17 in boys.

The growth of bones in child athletes occurs at the cartilaginous growth plates, called epiphyseal plates. These exist at the end of the bone shaft. The bone lengthens as the cartilage builds up and calcifies into bony tissue. There is a constant width of cartilage throughout the growing years until it calcifies after the growth has stopped—after puberty. The epiphyseal plate represents a weak spot in the bones of child athletes so that fractures along this plate can occur in an athletic injury. Damage to the epiphyseal plate can permanently affect the growth of the limb, with sometimes disastrous implications to growth.

The amount of muscle mass will increase as a child grows. In boys, puberty becomes a time in which there is a marked increase in muscle growth—even without physical activity. The hormonal changes that occur in puberty also change the body fat composition. At birth, both boys and girls will have a 10 to 12 percent body fat in terms of composition. Before puberty, there is also similarity between boys and girls, with a 16 to 18 percent body fat in both genders.

After puberty, the hormones in females, particularly estrogen, will increase so that the body fat in girls after this time will be 25 percent. This is what causes the female hips to widen and for extra fat to be present in this area. Boys after puberty will gain muscle mass so that their body fat percentage will be about 12 to 14 percent.

Athletic girls will keep a body fat of about 18 percent. Less than 12 percent body fat in females will decrease bone density and will disrupt the hormone levels—increasing the risk of stress fractures. Female athletes will also gain muscle mass up to the age of 19 so they will gain weight as a result. Unwanted weight gain can be avoided through proper eating, even as the female athlete continues to work out and gain muscle mass.

Female athletes are at risk for injury during puberty because of the widening of the hips, which changes the angle of the femur with respect to the rest of the body. This increased femur angle will result in inward rotation of the foot and knee. This can result in chondromalacia patella, a condition where the patella (knee cap) will not run smoothly in the groove of the knee joint. The end result is pain located at the front of the knee. Strengthening of the vastus medialis muscle, the abdominal obliques, and the lower abdominal muscles, as well as the hip abductor and external rotator muscles, will prevent this type of injury.

Another injury that is associated with bone growth is called a traction injury. This happens at the point in which the tendon and bone come together. Traction injuries vary with age and occur at different points in the child athlete's age, including the following body areas:

- Heel pain—this is called Sever's disease and is a result of outpacing of the heel bone with respect to the muscles and tendons that unite with the heal bone. It happens between 10 and 15 years of age and is more common in boys versus girls.
- Upper tibia—this involves pain in the tibial tubercle just beneath the knee at the point where tendons typically attach. This leads to pain with activity that is

treated with rest. It is more common in boys than in girls. The peak time is about 12 to 16 years in age.

- Lower back and iliac pain—this is seen when athlete's exercise and stems from pain at the attachment of ligaments and tendons as they fuse with the bone. It is more typically seen in later adolescence.

Traction injuries are rarely seen in non-athletes and almost always exacerbated by physical activity. The only known treatment for these types of injuries is to rest the affected body area.

It is a myth to believe that exercise in youth will either promote growth in height or stunt growth. It will, however, thicken the bones by increasing the amount of mineral deposited in the bones. Because growing bones are especially sensitive to stress, repetitive loading should be avoided. This is particularly true with regard to injury or undue stress placed upon the epiphyseal plate.

One injury that can occur to the epiphyseal plate in athletes is called epiphysitis. This involves repetitive strain on the epiphyseal plate where the tendons attach to the bone. There is an inflammatory response to excessive loads placed on the attached tendons. In severe cases, the epiphysis (the part of the bone on the far distal end of the bone) can attach from the rest of the bone at the epiphyseal plate. The most common type of epiphysitis is called Little Leaguer's Elbow. It is commonly seen in youth baseball pitchers.

With strength training in young athletes, increases in strength are possible. Those who use anabolic steroids as part of their training risk stunting of their growth caused by premature calcification of the epiphyseal plate, affecting mainly the long bones. In training these athletes, it is necessary to ensure that repetitive stresses are avoided and that young athletes are taught proper strength training without the use of steroids in order to maximize strength with as little injury as possible.

The aerobic abilities of the young athlete can be enhanced and will improve with training. They have smaller hearts but an increase in heart rate and VO2 max as compared to adults. Interestingly, the anaerobic capacity of the young athlete is highly limited as they lack the ability to have reasonable anaerobic capacity. Their glycogen and creatine phosphate stores are less compared to adults and they cannot generate lactic acid to the degree seen in adults. This means that weight training is best left to the adolescent or late adolescent athlete.

There are specific stages a child goes through in the training process that should be taken into account when training the young athlete. They start with the fundamentals, developing balance, agility, and coordination. Then comes foundation, which is the development of running, jumping, and throwing skills. They then develop the ability to participate in athletic events, getting the skills to participate in a specific sport. Finally, they develop the skills specific to the athletic event. Figure 23 describes this pyramid of athletic performance:

Childhood Athletic Performance Skills

Exercise and Childhood Obesity

While some children have medical conditions that lead to weight gain (such as Prader-Willi syndrome and Down syndrome) and still others have genetic disorders like congenital leptin deficiency (which affects appetite), most children are obese because of poor diet and a lack of adequate exercise. Heritable factors may play a role in many cases as well.

Nutritional factors include insufficiency of infant breastfeeding, a decrease in fiber, vegetable, and fruit intake, and the excessive consumption of fast food and soda, fueled by advertising that is geared toward enticing youth toward unhealthy eating habits. This is added to the significant decrease in energy expenditure by youth in Western society. Children are more sedentary than ever, largely because of increased screen time—more television watching, video games, and computer time.

Children at the greatest risk include those that do not participate in organized athletics. Girls are at a greater risk when compared to boys as are children in poverty, with disabilities, living in dangerous neighborhoods, and those in ethnic minority groups. Inactivity is twice as prevalent in girls versus boys and in particular, African-American girls. Children have fewer active role models and an increasing lack of recreational facilities.

Children are not getting enough physical education in schools, which is worse in high school compared to elementary school. While the National Association of State Boards of Education recommend up to 225 minutes of physical education for high school and middle school, these requirements are not getting met, with the average duration of physical education being 33 minutes twice per week. Attendance of physical education is only about 25 percent.

The benefits of managing obesity in children is better seen in younger age groups that benefit from the fact that they are increasing in height so they have the advantage of "growing into their weight." Management involves dietary modification, enhancing exercise among young people, and family-based behavioral modification in order to sustain weight loss measures in children. Television-watching should be restricted to less than two hours per day in children aged two years or older. Lifestyle-related physical activity is recommended versus regimented exercise.

Regular physical activity is important in the reduction of weight and in improving insulin sensitivity in young people who have type 2 diabetes. Blood pressure can be reduced in those kids who are hypertensive. Children with steatohepatitis have improvements in their liver function studies and reduction in liver size. There are also psychological benefits for all young people who exercise, regardless of their weight, decreasing anxiety and depression in children of all ages.

The recommendations for physical activity in children include the following:

- Children younger than two years of age should not watch any television. Infants and toddlers should be allowed to develop the enjoyment of physical activity and unstructured play under adult supervision.
- Preschool children should also be allowed unstructured play with a limit of two hours of television time per day. Walking should be encouraged versus the sedentary transportation by automobile and strollers.
- Children of elementary school age should begin building athletic skills by learning the fundamentals such as running, jumping, throwing, and participation in organized sports as long as the rules are relatively relaxed and flexible.
- In middle school, there should be an added emphasis on skill development and the acquisition of motor skills. Full development of vision, balance, and motor skills are achieved by late childhood so that, by middle school, participation in sporting activities that are more complex is feasible and recommended. Weight training should be initiated at this stage.
- Adolescents can begin acting on their own personal preferences when it comes to increasing physical activity and engaging in sporting events. Both competitive and noncompetitive sports are easily incorporated into the adolescent’s life.

Female Athletes

Female athletes need energy intake that balances energy expenditure in order to maintain a high level of training, building and repairing body tissues, preventing illness, and maintaining reproductive function. Low intakes of female athletes will increase the risk of injury, fatigue, illness, and menstrual irregularities, with impairments in protein synthesis, immune function, metabolic rate, and heart health.

For the active female, energy intakes less than 1800 kilocalories per day make it difficult to get the nutrients necessary for the maintenance of health and physical fitness. Female athletes who restrict their energy intake are likely to have low protein intake, which will adversely affect the energy balance. Micronutrients that tend to be low in the diets of active women include B-vitamins, calcium, vitamin D, zinc, and iron.

Female athletes who are significantly active may have energy needs much greater than the 1800 calorie a day minimum. Unfortunately, many female athletes still restrict their energy intake in order to lose body fat and to achieve a desired body size. When intake drops below 1800 calories, it is difficult to get enough in the diet in order to meet the macronutrient and micronutrient needs. Those who are active greater than 6 to 10 hours per week need around 2500 calories or more in order to maintain body weight. Competitive athletes exercising up to 20 hours per week should take in more than 3000 calories per day.

Optimal energy availability for the active female is about 45 or more calories per kilogram of fat-free body mass. Low energy availabilities are seen when this number drops below 30 calories per kilogram of fat-free body mass. If overall energy is low, then the energy availability might also be low. Too low of an energy intake can decrease the resting metabolic rate.

The female athlete with a relative energy deficit, either inadvertently or through purposefully disordered eating or dieting, can lead to fatigue, an increase in injury rate, and illness. Bone health can suffer as will menstrual health. These types of athletes will have impairment in metabolic rate, protein synthesis, immunity, and heart health.

Energy deficits can first be identified through oligomenorrhea (irregular periods) or amenorrhea (absent periods). Increased body mass index will generally lead to a restoration of menstruation, although it can take up to a year for this to happen. Weight loss during training is a sign of possible imbalances in energy availability. Young female athletes can also have slowed linear growth rates. Frequent injuries and illnesses can also be seen in energy availability decreases. Irritability and fatigue along with lightheadedness and shakiness during training are signs of low energy availability.

Poor macronutrient intake usually involves a lack of enough carbohydrates and protein in the diet. This can be due to overall energy restriction, limited food availability, loss of appetite during training, or avoidance of certain food groups (such as being vegan or restricting other classes of food). Athletes who are training hard need between 6 and 12 grams of carbs per kilogram of body weight daily. Foods considered healthy overall (such as whole fruits, vegetables, and whole grains) are also filling so they may contribute to not getting the carb intake recommended. These are low energy-dense foods that might be contributing to an energy deficiency.

Low protein intake are common in vegans who do not get enough animal protein. The goal for these athletes is to eat enough quality protein throughout the day. At least 1.2 grams of protein per kilogram of body weight should be the goal. Unfortunately, most of the research done on protein intake and protein requirements have been done in male athletes and not on female athletes.

Many female athletes with low energy availabilities are also low in fat intake. Remember that the recommended intake is about 20 to 35 percent of total energy intake. Intakes of less than 15 percent mean that there will be too little of the essential fatty acids taken in, particularly alpha linoleic acid, one of the omega-3 fatty acids. Several essential fatty acids are seen in fish and other marine food so that vegans especially will have low levels of these fatty acids in their diet. Overall fat intake is usually preserved in vegans that also choose to eat plant fats.

The major micronutrient deficient in female athletes who restrict intake is iron, which is found mainly in certain vegetables and red meats. Zinc, folate, and vitamin B12 are also nutrients that can be diminished in the female athlete who has energy restrictions.

Athletes who compete solely indoors can be deficient in the vitamin D derived from sun exposure. If these micronutrients are diminished, there can be problems with performance. Calcium can also be low if the right vegetables or milk are not eaten to a sufficient degree.

Female Athletic Triad

The female athlete triad or "the triad" refers to three separate things seen particularly in adolescent and young female athletes. It involves menstrual dysfunction, low energy availability, and decreased bone mineral density. The low energy availability does not necessarily mean there is an eating disorder because it can exist without a diagnosable eating disorder. The prevalence of this disorder is about two to five percent but it can be as high as 70 percent in individuals who participate in sports that emphasize thinness and aesthetics.

Disordered eating to some degree is highly prevalent in the athletic community, involving a wide variety of irregular eating behaviors that are not necessarily that of anorexia nervosa or bulimia nervosa. As many as 70 percent of elite athletes, particularly those who compete in activities that have weight classes, will be dieting at any given point in time, with elite athletes having up to 47 percent prevalence of eating disorders. This is far greater than is seen in the noncompeting athlete.

The prevalence of osteopenia is seen in up to 22 to 50 percent of female athletes, which compares to about 12 percent in the average population. Athletes participating in weightbearing activities typically have a higher bone mineral density than non-athletes. Athletes with a low mineral content in the bones have a much higher risk of fractures than those with normal bone mineral densities.

The findings in these studies indicate that, while the number of athletes having all three aspects of the triad is low, many athletes will have at least two of the three factors, at an incidence of up to 27 percent among female athletes. It should be noted that even having a couple of components of the triad will adversely affect the athlete's overall health.

Menstrual dysfunction includes a wide spectrum of menstrual disorders. Amenorrhea involves having an absent of menses for a minimum of three months or more. Primary amenorrhea is seen when the individual never reaches the age of menarche by the age of fifteen years of age. Secondary amenorrhea involves a loss of menses after the onset of menarche. Other menstrual irregularities include lack of ovulation, luteal phase defect (with short menstrual periods), and oligomenorrhea (missed periods).

Amenorrhea can be caused by any number of things in the athlete, mainly low energy intake and stress. The problem is due to suppression of the hypothalamic-pituitary-ovarian axis that does not have a specific organic cause. The normal pulsatile nature of the hormone secreted by the hypothalamus is not present so the pituitary gland and ovaries do not function. The end result is estrogen deficiency that secondarily contributes to low bone mineral density.

Energy availability involves the amount of energy available for all physiological functions after accounting for that energy expenditure used for exercise. Low energy availability can be seen in the absence of any known psychiatric diagnosis or eating disorder. They may fail to attain their energy requirements for other reasons, including not having adequate knowledge of nutrition and what their requirements should be. Many athletes simply do not have the appetite necessary to promote adequate food intake.

Female athletes are at risk of developing an eating disorder due to pressure to maintain a low body weight. Coaches can contribute to the problem by failing to teach athletes about proper eating habits and can contribute to the promotion of an unhealthy sporting atmosphere. Most disordered eating comes in those athletes who must compete in a weight class, endurance athletes, and those where aesthetics are important.

Anorexia athletica is a term used to describe a disordered eating pattern in female athletes but this isn’t a real medical term. The three main eating disorders seen in athletes are anorexia nervosa (with severe weight insufficiency with a body weight less than 85 percent of expected), bulimia nervosa (binge eating and purging), and EDNOS, which is an eating disorder, not otherwise specified. Excessive exercise tends to be a common feature of athletes who have difficulty with eating.

The greatest increase in bone mass happens during puberty with the maximal increases in bone mass happening between the ages of 11 and 14 years of age in adolescent girls.

About 25 percent of this occurs in the two years around menarche. Most healthy young women gain 92 percent of their overall bone mass by the age of 18 and gain 99 percent by the age of 26 years. Bone mass loss occurs later with the advent of menopause and aging.

Low bone mineral density and stress fractures can occur in the athlete who does not get enough energy to let bone density build. As mentioned, low estrogen levels will contribute to this low bone mineral density. The average athlete should have a greater bone mineral density than the non-athlete—particularly those engaging in weight-bearing activities. Those who do not have their periods tend to have a greater risk of a bone mineral deficiency. Stress fractures of the tibia are particularly common in the athlete with this problem.

The Older Athlete

We have already talked a bit about the fact that exercise is important at all ages. What we haven't talked about is the unique advantages of recommending exercise in the older individual and what considerations should be made for the older athlete. What should be clear by now is that any amount of activity in an older individual is far better than being sedentary. The greater the intensity, frequency, and duration of activity, the better the activity will be for the older person, even if they cannot achieve the recommended 150 minutes of moderate-intensity aerobic activity.

The incidence of inactivity in the person older than 65 years is as high as 33 percent. Only 16 percent meet the national guideline recommendations for physical activity—75 minutes of vigorous activity or 150 minutes of moderate aerobic activity per week. The major barriers to activity in the older adult include lack of motivation, lack of knowledge, and poor overall health.

The key recommendations for older adults when it comes to exercise include these:

- A reduction in sedentary time will have benefits to overall function and to the heart health.

- Resistance training will preserve muscle strength and functioning in the older adult.
- The overall goal is to get 150 minutes of moderate exercise and two days of strength training.
- Flexibility exercises might enhance the range of motion of the joints in older adults.
- Balance exercises such as tai chi can reduce falls in older adults at risk for falling.
- Physical activity decreases the risk of several chronic diseases.

Older adults are not uniform in their level of health and physical functioning. The normal aging process is associated with decreased strength and reduced functional capacity—things that can be overcome by helping the older adult be more athletic. There are a few things that need to be overcome in order to have a more athletic older person, namely cognitive impairment, a risk of falls, and chronic diseases, including musculoskeletal diseases that can impair the ability to exercise effectively.

Being sedentary in the older adult is linked to impaired glucose tolerance, type 2 diabetes, and an overall increase in mortality. By being active, the older athlete will have a reduction in cardiovascular disease, metabolic improvements, and enhanced functioning. Again, any amount of physical activity the older person does is considered better than not doing any physical activity.

In working with the older adult and in making exercise recommendations, it is important to be specific about what type of activity is being suggested, the frequency and intensity of exercise being discussed, and the long-term and short-term goals for the individual. The activity should be intense enough to increase the heart rate and respiratory rate with an understanding that a reasonable intensity of exercise is to be expected.

Light intensity of exercise is less than three METs. Remember that one MET is the amount of energy expended while sitting at rest. Light intensity involves casual walking, stretching, and light housework. Moderate activity (water aerobics, dancing, gardening, and brisk walking) is about 3 to 5.9 METs and is activity in which the adult can speak but with effort. Vigorous intensity is greater than 6 METs, in which no more than a few words can be said without stopping in order to breathe. These are things like heavy gardening, aerobics, and running or jogging.

Added to aerobic activity, which should be the major focus of the exercise an older person does, are things like strength training, balance training, and flexibility-enhancement. These are intended to lessen the risk of falls, improve muscle tone, and enhance the range of motion of the joints. Each of these will improve the overall level of function of the older adult.

The older individual who is relatively frail should start with strength training/resistance training first in order build muscle mass. This should be followed by balance and flexibility training and finally by aerobic training, which may not be possible initially due to poor muscle strength and lack of the balance and flexibility to engage in aerobic physical activity. The older individual who wishes to exceed the recommendations and to exercise more in order to enhance physical functioning should be encouraged to do so as there are no contraindications to being this active in the older adult.

The older adult who is unfamiliar with training and exercise may find it helpful to work with an experienced fitness trainer—one who has experience working with older adults and who understands their unique physiology and training needs. In some cases, physical therapy might be helpful in order to restore physical functioning so that the older adult can actually participate in a structured exercise program.

While aerobics have the greatest advantage in gaining cardiovascular and musculoskeletal benefits, resistance training remains the only exercise that consistently improves strength, muscle mass, muscle power, and overall physical functioning. These types of activities will help to counteract the decline in muscle power and strength normally seen as part of the aging process. Those adults who have joint flexibility will gain an advantage with doing flexibility exercises, particularly after doing resistance training or other activity that warms the muscles.

Even older adults who have chronic medical conditions can benefit from regular activity. Most older adults do not need formal exercise stress testing as long as low or moderate-intensity physical activities are stressed. It is, however, recommended in those older adults who have known coronary artery disease. Exercise is relatively contraindicated in individuals who have severe aortic stenosis or uncompensated heart failure.

Older adults with osteoarthritis might benefit from water-based activities, transitioning to land-based activities that can improve pain as well as functional aerobic capacity. Diabetics can benefit from exercise as well and will have an improvement in lipid levels, blood pressure, and glucose numbers. Combined aerobic and exercise training will improve the hemoglobin A1c levels more than doing either of these exercises alone. Those who want to do more than brisk walking or who have cardiac autonomic neuropathy should have exercise stress testing.

Obese older adults can benefit from physical activity. A weight loss of about five to seven percent due to exercise will result in an enhancement in mobility, lower extremity physical functioning, and overall improved physical functioning in the obese adult who is older. It should be known that, in older adults with unintentional weight loss, lean muscle mass is also going to be lost and there is a risk of decreased bone mineral density. These things can be counteracted by enhancing strength training. Bone mass density is most increased with resistance training versus just walking.

Exercise in the older adult has been known to enhance the cognition of those individuals who have mild cognitive impairment. It takes moderate exercise up to the recommended 150 minutes per week in order to reverse the mild cognitive impairment seen in some older adults. Even those adults with known dementia can have an improvement in physical functioning when they participate in regular physical exercise.

Key Takeaways

- Young athletes are changing developmentally, which affects their ability to participate in sports.
- The young athlete should start with the fundamentals before gaining skills in specific sports in order to participate competitively.
- Females run the risk of energy availability deficits when they participate in regular exercise and do not maintain at least 1800 calories of energy intake per day.
- The female athlete triad involves menstrual dysfunction, bone mineral density deficits, and energy availability deficits.
- The older adult will benefit from all types of activities that enhance physical functioning, with aerobic activity being the primary focus.
- Strength or resistance training is the only activity that will build muscle mass and will help bone mineral density losses the most in the older adult.

QUIZ

1. When does the peak increase in height change begin to occur in boys and girls?

    a. 8 years in girls and 10 years in boys
    b. 10 years in girls and 11 years in boys
    c. 11 years in girls and 13 years in boys
    d. 13 years in girls and 15 years in boys

    Answer: c. The peak height velocity or PHV in girls starts to increase at age 11 in girls and at 13 years in boys. This is followed by pubertal changes that last for several years after the growth spurt begins.

2. In understanding the growth and development of the child athlete, what is the epiphyseal plate?

    a. The growth plate of the long bones
    b. The place where the ligaments attach
    c. The place where tendons attach
    d. The connection point between the bones and the cartilage near the joint

    Answer: a. The epiphyseal plate is the growth plate. It is cartilaginous and is located near the end of the bone. Fractures to the epiphyseal plate can permanently affect the growth of the affected limb, being most severe when the child has not yet stopped growing.

3. Where is the pain located in child athletes who develop Sever's disease?

    a. Low back
    b. Knee
    c. Heel
    d. Hips

    Answer: c. Boys and sometimes girls with Sever's disease will have heel pain when the growth in their heel outstrips their tendon growth, leading to an increase in pain with pressure placed on the heel.

4. Epiphysitis is an inflammation and repetitive strain injury to the epiphyseal plate in athletes from overuse. What joint is most commonly affected in these types of injuries?

    a. Shoulder
    b. Elbow
    c. Knee
    d. Ankle

    Answer: b. Little Leaguer's elbow is the most common epiphysitis seen in athletes who are still growing. The injury is seen mainly in young male athletes who pitch baseball.

5. What is the first sign of an energy availability deficit in the female athlete?

    a. Stunted growth
    b. Oligomenorrhea
    c. Lightheadedness
    d. Weight loss

    Answer: b. The female body is set up to diminish menstruation when there is minimal food intake. This tends to lead to oligomenorrhea or amenorrhea in the athlete who is not getting enough intake, before any other symptoms occur.

6. What intake is particularly diminished in athletes who are also vegans?

    a. Vitamins
    b. Carbohydrates
    c. Unsaturated fats
    d. Protein

    Answer: d. Vegans tend to have an inability to get enough protein in their diet and some will have deficiencies of essential fatty acids, such as alpha linoleic acid; however, they will get enough plant fat so they won't be deficient in all unsaturated fats.

7. The athlete who has a lack of onset of menarche by the age of fifteen is said to have what?

   a. Secondary amenorrhea
   b. Oligomenorrhea
   c. Luteal phase defect
   d. Primary amenorrhea

      Answer: d. Primary amenorrhea is defined as a woman or teen who has not achieved the onset of a menstrual period or menarche by the age of fifteen, usually because of lean body weight and disordered eating in an athlete who is competing in those sports that emphasize thinness.

8. In the female athlete triad, what is the gland that is most responsible for the dysfunction in the menstrual cycle?

   a. Hypothalamus
   b. Pituitary gland
   c. Thyroid gland
   d. Ovaries

      Answer: a. The normal hypothalamic function, which should lead to pulsatile gonadotropin releasing hormone levels, is not adequate, leading to a lack of functioning of the entire hypothalamic-pituitary-axis and amenorrhea.

9. In the exercising older adult, what should the major focus of the exercise be?

   a. Balance training
   b. Flexibility training
   c. Strength training
   d. Aerobic training

      Answer: d. Aerobic training should be the mainstay of the exercise an older adult does as this provides the most heart and metabolic improvement, although all of these activities have proven benefit to this group of individuals.

10. In the older adult who begins training relatively frail, what type of activity should be started first?

a. Balance training
b. Flexibility training
c. Strength training
d. Aerobic training

Answer: c. Strength training should be started first in order to build muscle mass necessary to participate in any of the other types of training activities.

Chapter 10: Cardiovascular Disease and Pulmonary Disease with Exercise

This chapter discusses exercise as it applies to individuals with cardiovascular or heart disease, those who have COPD (chronic obstructive pulmonary disease), patients with emphysema, and athletes or prospective athletes with asthma. People with these disorders have special challenges related to exercise and must make adjustments to their exercise program in order to be active. This isn't to say that these are individuals who cannot exercise; on the contrary, they can exercise and may enhance their physical fitness levels and levels of functioning in daily activities through exercise.

Exercise and Heart Disease

It is well known that exercise can prevent heart disease in those who engage in regular physical activity prior to actually having the disease. But, for those with a risk for heart disease, it takes a combination of healthy eating and regular exercise to reverse many heart disease factors.

The heart is like any muscle that needs to be exercised. Muscles that are used regularly will become stronger and healthier, while muscles that are not regularly exercised can become weak and atrophied. The exercised heart will pump more blood through the body with a greater degree of efficiency when compared to the non-exercised heart. It is believed that exercise will help the heart remain healthier for a longer period of time. The same holds true for exercise and the blood vessels, which will become more elastic and will have enhanced blood flow at more normal blood pressures than seen in those who do not exercise.

There are as many as 250,000 deaths in the US that are directly related to a lack of regular exercise. In fact, being sedentary is considered one of the top five risk factors for heart disease. The other risk factors include elevated cholesterol, high blood pressure, smoking, and obesity. It is well known that individuals who do not participate in regular exercise have a higher risk of cardiovascular events of any kind and a higher risk of death. These individuals also have a higher risk of developing hypertension, which is itself a risk factor for heart disease.

Exercise has been found to stimulate the nitric oxide levels in the bloodstream, which is a molecule that keeps blood vessels open and blood flowing. Exercise is also one of the few things that will raise the level of HDL or “good” cholesterol. The LDL (bad) cholesterol and triglyceride levels will reduce. Heart attack victims who participate in formal exercise after their event will have a reduction in death rate by 20 to 25 percent. Those who exercise have a 50 percent reduction in heart disease compared to those who are sedentary. Heart failure patients will also have an improvement in quality of life.

The American Heart Association recommends 150 minutes of some type of moderate physical activity per week as being the most beneficial in preventing heart disease. Research indicates a 14 percent reduction in heart disease in those who exercise this much. Other research indicates that as little as 10 minutes at a time done several times per day can be beneficial.

People with heart disease should exercise on a regular basis. For those who exercise, there will be an increase in the level of activity that can be accomplished without chest pain. It will also lower blood pressure and total cholesterol and will improve glucose tolerance. Weight loss is also possible with exercise and bones will strengthen.

In this way, exercise can play a role in the secondary prevention of cardiovascular disease. Secondary prevention means the prevention of heart disease after an event has already occurred in order to prevent a further occurrence of disease. This is in contrast to primary prevention, which involves prevention of disease before it has occurred, which is also seen with respect to heart disease.

Exercise training will increase the cardiovascular functional capacity and decrease the myocardial oxygen demand at any level of physical activity (even at rest) in individuals who have heart disease. It requires, however, ongoing efforts in maintaining a higher level of activity in order to sustain these benefits. The risks of exercise in these individuals can be reduced by having an initial medical evaluation, risk stratification to identify those at higher risk of complication, education of heart disease patients, and supervision of their exercise program.

Among heart disease patients with elevated blood pressure, a decrease of 8 to 10 millimeters of mercury in both diastolic and systolic blood pressure measurements can be seen. There is not only a direct relationship between physical activity and heart disease mortality but a dose response relationship so that exercising more means greater benefit. The greatest benefit for reduced mortality is in sedentary people who later become moderately active.

It appears to take more than just regular exercise to have regression of the atherosclerotic lesions in the coronary arteries of patients who have heart disease. Exercise must be combined with smoking cessation, blood lipid reduction, and weight control, which often requires the addition of healthy eating, in order to have an effect. The higher the level of exercise, the greater is the left ventricular ejection fraction (stroke volume) in people with heart disease.

In a prior chapter, we talked about the VO2 max or the maximal amount of oxygen that can be consumed in a minute of heavy exercise. This is a test that requires a formal exercise test. It can be estimated by taking 15 times the heart rate max divided by the resting heart rate. What we didn't talk about is the VO2 reserve, which is the VO2 max minus the VO2 at rest. Exercise that helps the heart should happen in the range of 40 to 85 percent of the VO2 reserve or heart rate reserve. Figure 24 shows these calculations:

Exercise Calculations in Heart Disease

VO2 max = 15(heart rate max/heart rate resting)

Heart Rate Max = 220 minus age

VO2 reserve = VO2 max - VO2 resting

Heart Rate Reserve = heart rate max - heart rate resting

Exercise intensity = 40-85% of VO2 reserve or HHR

If the individual cannot be tested, it is recommended to start at 20 to 30 beats per minute above the heart rate at rest until testing can be performed. Patients with heart disease can use a heart rate monitor in order to keep an ongoing record of their heart rate during exercise or can use a treadmill that monitors their heart rate while walking or jogging.

This leads us to a discussion of the Borg scale, which is a measurement of the rate of perceived exertion in the exercising person. It is an arbitrary scale, ranging from 6 to 20, which is used to measure the rate at which an activity is done. According to the scale, these are the basic measurements:

- Less than 12—heart rate is 40 to 60 percent of maximum and light intensity of exercise
- RPE of 12-13—heart rate is 60 to 75 percent of maximum and moderate intensity of exercise
- RPE of 14-16—heart rate is 75 to 90 percent of maximum and high intensity of exercise

Many individuals will need to start at a light intensity before working up to moderate intensity exercises, in which the individual can talk but is winded with talking. High intensity of exercise involves being unable to say more than a few words without being short of breath. As a safe level of activity is established, the duration is increased by five minutes per week with the heart rate response noted. If the heart rate response decreases as the individual is better condition, the intensity and frequency of exercise can be increased. Resistance training is also safe for secondary prevention of heart disease.

The patient with cardiac ischemia will have a variable response to exercise and will need medical supervision in order to be able to exercise. Signs of probable ischemia include the following:

1. Ventricular tachycardia—more than three beats emanating from the ventricles instead of the atria
2. Any arrhythmia that becomes symptomatic or results in low blood pressure

3. Any type of chest discomfort that is believed to be angina
4. Significant ST depression on an ECG or electrocardiograph
5. Inappropriate elevation or depression in the systolic blood pressure with exercise

Ideally, these individuals should be able to exercise but the heart rate maximum during exercise should be at least 10 beats per minute less than the heart rate associated with evidence of ischemia. They need to be carefully monitored with stress testing done at least once per year.

After a heart attack, early walking should be implemented along with range of motion of the upper extremities. The emphasis of exercise in the first two weeks after a heart attack should be on the avoidance of the negative effects of bed rest and inactivity. As the individual improves, activity should be increased as long as there is no evidence of ischemia with activity. Ultimately, after cardiac rehabilitation in a structured setting, the person should be able to eventually exercise in a non-structured setting at home or with a trainer.

Exercise and COPD

Patients with COPD have what's called "chronic obstructive pulmonary disease" or emphysema. It is almost always caused by smoking, either actively or through passive exposure to cigarette smoking. The sufferer has shortness of breath with exertion and sometimes with rest due to lung damage and impaired ventilation. In many cases, there is inflammation and narrowing of the airways, and consolidation of the alveoli so that the alveoli become quite large and adequate ventilation is impossible, even under resting circumstances.

Many people with COPD feel that they cannot exercise because of shortness of breath and the belief that exercise will worsen their lung condition. On the contrary, too much inactivity when a person has COPD will worsen their functionality and decrease their overall level of fitness. Exercise will not worsen the COPD and is recommended, even if the individual is short of breath at rest.

Exercise alone will not reverse the damage done to the lungs by COPD. Only smoking cessation can halt the process but will not reverse it. Exercise can improve the COPD patient's breathing and level of function so that they can be symptomatically improved. As with heart disease, the person should start slowly and should gradually increase their level of activity so as to work up to a reasonable activity level. A minimum of three days per week is recommended, although more would be better.

The level of exercise recommended can be determined by the exercise stress test. In such cases, the stress test can monitor the level of exercise not only when it comes to the heart rate but also with regard to the oxygenation status. The oxygen level can be determined during exercise with oxygen recommended for individuals who require oxygen not just for perceived shortness of breath during exercise but for documented low levels of oxygen during the test. Some individuals will need a pulmonary rehabilitation program, which is a great deal like cardiac rehabilitation after a heart attack but is focused on maximizing exercise in individuals with lung disease.

Many people with shortness of breath because of COPD believe they cannot exercise. While everyone who exercises will experience shortness of breath, the person with COPD cannot adjust their breathing during exercise in order to meet the increased need for oxygen. Breathing becomes fast and proper exhalation cannot occur. Added to this is the fact that COPD patients cannot easily exhale the air in their lungs, contributing to shortness of breath. This is why the person with this disease will have "pursed-lip" breathing in order to empty their lungs faster. In fact, this type of breathing can help the person with COPD in exercising.

The person who has COPD should stretch and breathe slowly prior to exercise in order to warm up the body and increase the lung capacity through several minutes of active stretching. As always, aerobic activity should be recommended primarily, which can involve walking, biking, or stair climbing. About 20 to 30 minutes of activity should be considered at a time for a minimum of three times per week. Slowly increasing the activity before maximal effort and slowly decreasing the activity after maximal effort should be undertaken.

As in other exercise programs, the focus should be on aerobics, but strength training can also help the person with COPD. Both upper and lower body strength training should be done in order to improve the ability to function during the exercise process and in daily living. Because these types of exercises are important as well, they should be done at a rate of about three times per week.

The Borg Scale of perceived exertion with exercise is helpful in the COPD patient who chooses to exercise. It helps the active person gauge their degree of exercise with the goal to stay at a moderate level of exercise—so that speech is possible but that the person feels winded. It can replace monitoring the heart rate during physical activity.

For the COPD patient, exercise should be possible to some degree, even when the person feels mildly short of breath at rest. The restrictions on exercise should be limited to having chest pain with exercise, fever, unexplained leg pain with exercise, or nausea with exercise. The person who requires oxygen at rest should use oxygen during exercise in order to reduce the perception of shortness of breath; the flow rate will often need to be adjusted upward with exercise, starting at about five minutes before the activity.

EXERCISE AND ASTHMA

Asthma involves reversible airway disease, usually resulting in shortness of breath because of a trigger, which can be an infection, an allergy, stress, or even exercise. Asthmatics are said to have "reactive airway disease" because their airways are prone to bronchospasm—spasm of the bronchial tree muscles—along with inflammation of the airways. This problem can lead to shortness of breath, made particularly worse with exercise.

Exercise-induced asthma is shortness of breath and wheezing during exercise primarily. Wheezing involves a high-pitched breathing sound usually heard during expiration that comes from airway narrowing and the sounds the air makes when passing through the airway. Many sufferers will have coughing during or after exercise and will be more likely to be short of breath with exercise than the average person.

About 80 percent of people with asthma will have a significant attack provoked by exercise. Individuals who do not have asthma can have a reduction in airflow of the airways secondary to heavy exercise even though the natural response to exercise is that of mild dilation of the upper airways. It takes about five minutes of continuous exercise to have bronchoconstriction but it doesn't have to be maximal exertion to have an asthmatic response to exercise.

Even elite athletes can have bronchospasm and exercise-induced asthma. The sports that primarily result in this phenomenon are running, swimming, cycling, and all winter sports. The problem with exercise-induced asthma is that it causes children to decrease their level of physical activity and may decrease their fitness level as a result. For this reason, efforts to treat these children so they can exercise should be maximal.

No one knows exactly why exercise triggers bronchospasm. It may be due to drying of the airways in exercise or the effects of cold air on the airways when breathing is rapid and air isn't warmed enough during activities. Air pollution is also a probable trigger. In addition, as many as 90 percent of asthma patients will have some type of nasal congestion or "rhinitis." Around a third of people with allergic rhinitis have reactive airway disease.

Elite athletes have more problems with exercise-induced asthma than the regular person with about 23 percent of summer athletes and about 55 percent of winter athletes having this problem. Those who participate in endurance sports have the greatest risk. Because cold air triggers asthma and organic chlorine products in swimming pools trigger asthma, athletes exposed to these substances will have the greatest risk of bronchospasm.

The main reason for endurance athletes having a higher risk for this disorder is that they have recurrent damage to the lining of their respiratory tract from the increased ventilation necessary when training along with a reduced chance for recovery and repair at this level of training. There is increased inflammation of the airways because of this; however, the problem appears to be reversible with a decreased intensity of exercise.

Because of their unique situations, marathon runners have a 42-fold increased risk for exercise-induced asthma and swimmers have a 92-fold increased risk for the disease. Those sports with the least impact on bronchospasm are those that are of short-duration, like sprinting, and those that do not require high ventilation levels. Team sports are one of the least risky sports as they require shorter periods of activity over time. While swimmers breathe in warm, humid air, the chlorine is thought to cause an increase in bronchospasm. Chemicals in ice rinks make indoor ice skating more problematic.

An exercise stress test or an in-field exercise test can help to identify the athlete at risk for exercise-induced bronchospasm. The test can be done before and after giving an inhaled beta-2-agonist drug like albuterol to see if a reversible airway problem exists. Drugs like albuterol are not banned by the World Anti-Doping Association or the International Olympic Committee so the athlete can use them without having to take a formal exercise test to identify the problem.

It generally takes very high workloads to achieve the kinds of bronchospasm issues seen in many athletes. The target workload must be nearly 80 percent of maximum for a minimum of four minutes to prove or disprove that a problem exists. There are other tests, such as histamine and methacholine challenge tests, that can be very sensitive in diagnosing reactive airway disease.

The athlete with exercise-induced asthma is treated like any other person with asthma. The emphasis should be on treating these people so they can exercise maximally. This is because exercise, even for the regular person with asthma, is important to lung function. The recommended treatment is inhaled corticosteroid drugs because they address inflammation, which is the underlying problem with these individuals and because they can be used on a regular basis—even on days the athlete does not exercise.

If the first-line corticosteroid treatment does not completely resolve the problem, the second-line treatment is a short-acting inhaled beta-agonist like albuterol. These are used before exercise and take just a few minutes to kick in. Long-acting beta-agonists can be used next, followed by inhaled ipratropium, which can further decrease inflammation. None of these drugs is restricted by anti-doping organizations because they do not improve performance in those athletes who do not need them. Only oral corticosteroids, oral beta-agonists, and intravenous beta-agonists are prohibited.

Key Takeaways

- There is a clear benefit to the heart with exercise; it affects most parameters of heart health in order to improve cardiovascular function.
- The person with heart disease can, with exercise and improvement in other cardiovascular risk factors, improve coronary artery disease.
- After a heart attack, the affected person should be allowed to walk shortly thereafter.
- Individuals with COPD or emphysema should participate in exercise to maximize their overall level of functioning.
- Elite athletes have a higher risk of exercise-induced asthma because of their high level of exercise for long periods of time.
- Endurance sports, swimming, and outdoor sports carry a higher risk of causing exercise-induced asthma.

QUIZ

1. What will least likely be improved with regard to the cardiovascular system in the exercising adult at risk for heart disease?

   a. Blood vessel elasticity
   b. Blood pressure
   c. Cardiac contractility
   d. Each of these will be improved with exercise

      Answer: d. Exercise has only positive effects on the individual's cardiovascular health, with improvements in cardiac contractility, reduction in blood pressure, and increases in blood vessel elasticity. These will improve the overall cardiovascular health of the exercising individual.

2. According to the American Heart Association, 150 minutes of exercise are recommended each week. What percent reduction in heart disease is seen in those who exercise at this level?

   a. 4 percent
   b. 14 percent
   c. 24 percent
   d. 34 percent

      Answer: b. While not tremendous, a fourteen percent reduction in heart disease is seen when 150 minutes of exercise is performed each week.

3. For an individual to reduce the risk of heart disease or prevent heart disease, what is the recommended exercise level?

   a. 85 percent of maximum heart rate
   b. 40-85 percent of heart rate reserve
   c. 150 percent of resting heart rate
   d. 20-40 percent of heart rate at rest

Answer: b. The recommended exercise level is 40 to 85 percent of the heart rate reserve or VO2 reserve. The heart rate reserve is the maximum recommended heart rate minus the resting heart rate and the VO2 reserve is the VO2 max minus the VO2 at rest.

4. When evaluating and recommending exercise to a heart disease patient, what is the Borg scale?

   a. Heart rate during exercise
   b. Respiratory rate during exercise
   c. Step rate of exercise while walking
   d. Rate of perceived exertion during exercise

   Answer: d. The Borg scale is a measurement of the rate of perceived exertion during exercise. It is used to measure whether or not the exercise is of mild, moderate, or extreme intensity.

5. What should the exercise level be for the heart attack victim after their event?

   a. No activity for two weeks
   b. Walking shortly after the cardiac event
   c. Stress testing before any activity is performed
   d. No restrictions on activity

   Answer: b. Because of the adverse effects of bedrest on the heart attack victim, walking should be instituted shortly after the activity. After they are ready to do more than this, a stress test can be done to see how much activity should be done in the weeks and months after their event.

6. When should the COPD patient avoid physical exercise?

   a. If they have shortness of breath at rest
   b. If they have shortness of breath with walking
   c. If they continue to smoke
   d. All COPD patients should exercise

Answer: d. Patients with COPD should exercise, even if they are short of breath at rest because their inactivity will only worsen their respiratory fitness so they will get weaker over time.

7. What is least likely to be seen in individuals with asthma?

   a. Shortness of breath with exercise
   b. Fever
   c. Bronchospasm
   d. Inflamed airways

   Answer: b. Each of these can be seen in the person who has asthma; however, unless there is an active infection, fever is not seen with this disorder.

8. What percent of asthma patients will have exercise provoke an asthma attack and will have an exercise component to their airway disease?

   a. 10 percent
   b. 30 percent
   c. 60 percent
   d. 80 percent

   Answer: d. As many as 80 percent of asthma patients will have an asthma attack provoked by exercise. This isn't to say that they do not have a component of their disease process that is unassociated with exercise.

9. What is least likely to be a trigger for exercise-induced bronchospasm in the athlete?

   a. Dry air
   b. Chlorine
   c. Cold air
   d. High altitude

   Answer: d. Each of these is believed to be a trigger for exercise-induced bronchospasm; however, high altitude is not a recognized trigger.

10. Why do endurance and elite athletes have more bronchospasm with exercise than other people?

    a. They are exposed to more air pollution that most people.
    b. They have increased airway lining damage than most people.
    c. They need greater volumes of air during exercise than other athletes.
    d. They do not have a greater incidence of asthma when compared to other athletes.

        Answer: b. The heavy levels of activity seen in the endurance and elite athlete lead to increased damage to the respiratory lining (the airways) that doesn't get repaired by resting so they have more inflammation in the airways.

CHAPTER 11: OBESITY AND EXERCISE

The topic of this chapter is obesity and exercise. The obese person should be able to exercise despite being overweight and may lose weight as a result of their exercise. In fact, very few people can lose weight and sustain their weight loss without some form of physical activity. The types of physical activity that can safely be undertaken in the obese patient and how much exercise should be done to lose weight are discussed in this chapter.

OBESITY AND EXERCISE

Obesity has a negative effect on the health of the individual and accounts for about 5 to 10 percent of all US healthcare dollars. According to statistics, about 60 percent of all US adults are overweight, which is defined as having a body mass index of about 25 to 29.9. About 22 percent of all adults are obese, which is defined as having a body mass index of 30 or more. It is believed that the incidence of obesity is increasing. Diseases most linked to obesity include diabetes, cancer, hypertension, heart disease, and elevated lipids.

Weight loss in obesity requires a reduction in caloric intake as well as increased physical activity (which is considered output). As for intake, the goal is to have a reduction in the total caloric intake but to eat enough to get the number of calories required to get the necessary macronutrients. You should know that a pound of fat is equal to 3500 calories. This means that, in order to lose weight, the individual should decrease calorie intake and decrease dietary fat intake to less than 30 percent of total calories and should exercise to increase output.

As we discussed in a previous chapter, the number of calories expended through exercise is around 200 to 600 calories per hour of exercise. This means it would take days of exercise to lose weight without dieting as well. The advantage of exercise is two-fold. It will increase the amount of muscles versus fat and muscles will burn more calories than fat. This translates to an increase in basal metabolic rate overall. In addition, the metabolic rate will remain elevated for hours after exercise so exercise will burn more calories, even after the exercise is over.

The basal metabolic rate is the rate the body burns at rest. Eating too little will have the overall effect of having the body reduce its basal metabolic rate to adjust for what it perceives as starvation. This is why the obese person needs to eat at least at a level that will maintain an adequate basal metabolic rate. Figure 25 shows the basal metabolic rate or BMR calculation:

Basal Metabolic Rate (BMR) Calculations

For a man, the BMR is equal to: 66 + (6.23 x weight in pounds) + (12.7 x height in inches) - (6.8 x age in years).

For a woman, the BMR is equal to: 655 + (4.35 x weight in pounds) + (4.7 x height in inches) - (4.7 x age in years).

Next figure out the total daily caloric requirement by multiplying your BMR by your level of activity:

- If rarely exercising, multiply the BMR by 1.2
- If exercising 1 to 3 days per week, multiply the BMR by 1.375
- If exercising 3 to 5 days per week, multiply the BMR by 1.55
- If you exercise 6 to 7 days per week, multiply the BMR by 1.725
- If exercising every day and have a physical job, multiply the BMR by 1.9

The average basal metabolic rate (BMR) for women is about 1,400 calories while for a man it's about 1,800 calories per day. For this reason, this is generally the minimum number of calories necessary for adequate biological functioning. Going beyond this, even for an inactive person trying to lose weight can slow the BMR to an even lower degree. In addition, it is important to stress that exercise alone isn't the only answer to weight loss; it takes a combination of exercise and a low-calorie diet to have a maximal effect on weight loss.

The main comorbidities seen in obesity that can affect the ability to exercise include metabolic diseases like diabetes, osteoarthritis, and heart disease. These can be barriers to maximally exercising for weight loss. Even so, most of the time the individual can exercise to some degree; exercise is likely to increase the chances of being able to maintain weight loss successfully.

Obese individuals who are candidates for physical activity should be evaluated for their ability and readiness for exercise. The Physical Activity Readiness Questionnaire or PAR-Q is a way to determine whether or not a person should be screened more deeply. Figure 26 shows this questionnaire:

Physcial Activity Readiness Questionnaire

YES NO
□ □ 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
□ □ 2. Do you feel pain in your chest when you do physical activity?
□ □ 3. In the past month, have you had chest pain when you were not doing physical activity?
□ □ 4. Do you lose your balance because of dizziness or do you ever lose consciousness?
□ □ 5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
□ □ 6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
□ □ 7. Do you know of any other reason why you should not do physical activity?

Coronary artery disease risk factors include smoking, positive family history, dyslipidemia, hypertension, obesity, diabetes, and sedentary lifestyle. High HDL-cholesterol levels are a negative risk factor against heart disease. Low-risk individuals are asymptomatic men under 45 years and asymptomatic women under 55 years with no more than one risk factor. Moderate-risk individuals are those men 45 years and older and women 55 years and older with two or more risk factors. High-risk individuals are those who have signs and symptoms of cardiac ischemia with exercise or those who already have heart disease. High blood pressure is considered a greater risk factor than most because exercise can worsen this condition.

Moderate and high-risk individuals should have preparticipation cardiac stress testing performed to make certain there isn't evidence of cardiac ischemia. It can also help to determine the individual's VO2 max if this is desired to see where the individual falls on the spectrum with regard to aerobic capacity. This can help derive an exercise prescription for the obese individual. Other aspects of an evaluation can include getting a weight history, determining the body composition, and getting a nutrition history.

The exercise prescription involves defining the mode, intensity, frequency, and duration of the individual's exercise activities. There should be a warm-up, conditioning phase, and cooldown. The warm up should be at least five minutes in length and should prepare the muscles which helps reduce injury risk. The conditioning phase involves 20 to 60 minutes of aerobic or fitness training. The cooldown phase should be a minimum of five minutes and should help remove lactic acid, dissipate body heat, and slow the rise in catecholamines seen with exercise.

Because the direct measurement of the VO2 max is difficult and may not be necessary, the heart rate is often used instead. The recommended aerobic training phase is 50 to 85 percent of heart rate reserve or about 70 to 94 percent of maximum heart rate (as calculated by taking 220 minus the age of the person). The lower end of this range is what is physiologically acceptable, while the upper end of this range is what should be reserved for trained individuals. Intensity above this range is considered anaerobic and does not offer an advantage.

In the beginning, the person should start out at a minimum of 20 minutes and increase to 60 minutes. If the exercise becomes easier, there should be an increase in duration or frequency first and then an increase in intensity of exercise. Resistance training is recommended but should not be used alone because it will not increase the VO2 max, expends only a moderate number of calories, and only mildly affects the resting metabolic rate.

The main priority in managing the care of an obese person is to prevent additional weight gain. Secondary goals include reduction of body weight and long-term maintenance of weight loss. The normalization of body weight is too great a target so that slow steady weight reduction is more appropriate. The target is 5 to 10 percent reduction in weight. The maintenance of exercise is most predictive of long-term success in weight loss.

The volume of exercise necessary for weight loss is greater than that necessary to improve fitness. The initial training intensity should be about 40 to 60 percent of heart rate reserve. The obese person may not be able to walk briskly but they should be able to do something less than that to bring the heart rate up. Training frequency should be five to seven days per week with sessions lasting 45 to 60 minutes each. Remember that glycogen is the main fuel source utilized in the first 20 minutes of exercise, followed by fatty acid oxidation after thirty minutes. Obese individuals should exercise at a level of 250 to 300 minutes per week in order to lose weight and maintain that weight loss. Intensity should be at 55 to 69 percent of maximum heart rate.

Obese people may benefit from some type of resistance training even though it does not burn as many calories as aerobic exercise. It does improve muscle strength and enhances functional tasks. It will also increase the fat-free mass but does not result in absolute weight loss by itself.

Exercise for Weight Loss

It is widely believed that weight problems and the high rate of obesity in Western society is a combination of increased caloric consumption along with decreased physical activity. It is not the overconsumption of any one thing but the general overabundance of energy-dense foods and a lack of regular physical activity over a prolonged period of time that has caused these health problems. It accounts for impaired functioning in many people and is a risk factor for many diseases. Exercise is better for the prevention of obesity but it can also be used for and the maintenance of weight loss.

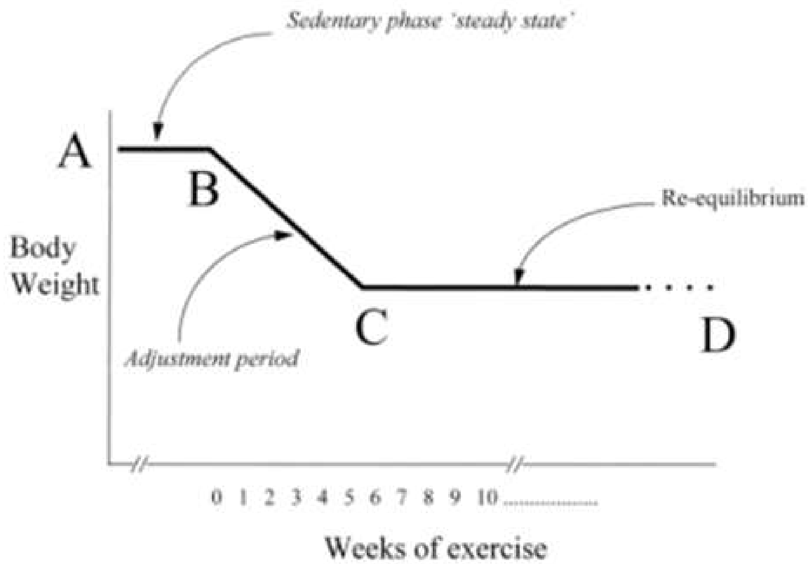
While it is generally well-established that 30 minutes of exercise are recommended for physical fitness and the improvement of heart and metabolic functioning. This is not, however, what is recommended for weight loss. Remember that fat stores do not begin to burn until 20-30 minutes of exercise have occurred. For this reason and others, the recommended amount of exercise for weight loss should be 45 to 60 minutes per day, preferably at one time, for overweight individuals and potentially more than that for obese individuals.

In order to lose weight, a weight loss of about one to two pounds per week is considered both safe and effective. This requires the extended difference of about 500 to 1000 calories per day. This amount of weight loss is difficult to manage through food intake reduction alone because this can lead to nutrient deficiencies and is difficult to sustain. Exercise has the dual advantage of adding to the negative energy balance and to help improve the fat to muscle ratio so that muscle loss does not happen along with fat loss.

The data suggest that exercise alone is insufficient to actually lose body weight. It would take sixty minutes a day of walking at 3.5 miles per hour for the average man to expend 475 calories daily or for the average woman to expend 384 calories per day. This will not allow for meaningful weight loss of one to two pounds a week. It would take nearly 120 minutes of exercise for the obese woman to lose weight just through exercise. There is some increased metabolic rate after exercise and some increased metabolic rate because of higher muscle to fat ratios but this is not enough to actually lose weight.

The body will have the capacity to adapt to the total energy expenditure in the face of increasing activity so that even increasing the amount of activity done per day, the weight loss achieved is limited by this adaptive response. This is believed to be because of non-exercise time temperature adjustments in the body. What this means is that both exercise and calorie restriction are necessary to lose weight. The amount of exercise necessary for meaningful weight loss without calorie restriction is unlikely to be possible or sustainable. This phenomenon explains the frequent plateaus seen in weight loss. Exercise can, however, help prevent weight gain. Figure 27 shows what happens to weight loss with exercise alone:

Weight Loss with Exercise



One of the problems with losing a great deal of weight is that many people quickly regain it because there are metabolic adaptations to exercise and restricting calories. Those who combine exercise and calorie restriction will be more successful in maintaining a lower body weight over the long haul. In addition, the amount of activity necessary to prevent weight gain after obesity is very high in comparison to the modern active lifestyle. Because of this, the International Association for the Study of Obesity recommends 60 to 90 minutes a day of moderate activity or 35 minutes of vigorous activity to maintain weight loss successfully after obesity reversal.

Resistance training, as mentioned, is helpful but does not work alone in order to promote weight loss. Eating protein and resistance training does, however, protect the amount of lean body mass during the weight loss process. Research on calorie restriction and resistance training shows that the combination of these will improve metabolic and cardiovascular risk factors but resistance training alone will not change weight or improve risk factors. Even so, resistance training in older adults in particular is recommended to prevent losses of lean body mass. In addition, the combination of resistance training and aerobic activity together will improve functionality in the older adult.

Weight loss success involves the total daily accumulated energy expenditure so that getting intermittent exercise can result in similar weight loss in obese subjects but with improved adherence over the long term compared to a single episode of exercise daily. This means that the integration of more physical activity overall may be just as successful as a structured exercise program. Again, the combination of calorie restriction and exercise is recommended for both weight loss and the maintenance of weight loss in those who were once obese or overweight.

About 10 percent of adults in the US use activity tracking devices to assist with their weight loss. Most of the affordable ones are restricted to measuring steps and overall distance traveled. There are those that will measure activity duration, energy expenditure, oxygen levels, blood pressure, and sleep quality but with limited accuracy. There are devices being engineered that will do even more than these things and may measure metabolic parameters like lactate levels and glucose levels.

What isn’t known is whether these activity monitors will increase the motivation to exercise. Research has shown that these devices are most owned by people who least need them. They tend to be used by people who are wealthier and younger and not by older people and not by people of low economic status. There is a big gap between what a person knows about their physical activity and what they institute as part of their behavior. They are best used by runners and walkers but will miss capturing other kinds of activities.

It should be noted that exercise works best in the prevention of obesity and is less effective in reversing it. High intensity interval walking programs are sufficient to improve heart disease risk factors and peak aerobic capacity in individuals who are sedentary and middle-aged. As mentioned, the effect of exercise on and the maintenance of weight loss is only really a positive one as long as the overweight person also continues to restrict calories after the weight loss has already occurred.

Key Takeaways

- Exercise plays a strong role in the ability to lose weight.
- Weight loss is associated with an improvement in metabolic parameters and heart disease risk.
- It takes a combination of exercise and calorie restriction in order to lose weight and maintain the weight loss after it is achieved.
- Exercise is better at preventing weight loss and not as good at causing weight loss alone.
- Calorie deficits of about 500 to 1000 calories per day are necessary in order to lose one to two pounds a week.
- Resistance training has some benefit but is not helpful by itself in weight loss or improvement in metabolic parameters in obese individuals.

QUIZ

1. What body mass index level defines a person as being overweight?

    a. 18 to 22
    b. 18.5 to 25
    c. 25 to 29.9
    d. 30 to 34.9

    > Answer: c. A body mass index or BMI of between 25 and 29.9 is considered overweight. BMI levels between 18.5 to 25 is normal and obesity is defined as a body mass index above 30.

2. What disease is not closely linked to obesity?

    a. Kidney disease
    b. Type 2 diabetes
    c. Hyperlipidemia
    d. Coronary artery disease

    > Answer: a. Each of these is closely linked to obesity except for kidney disease. The only connection between obesity and kidney disease is that type 2 diabetics can develop kidney disease over time, depending on their other risk factors.

3. What is the average basal metabolic rate for adult men and women?

    a. For men, it is 1800 calories and for women, it is 1400 calories
    b. For men, it is 2200 calories and for women, it is 2000 calories
    c. For men, it is 1200 calories and for women, it is 1000 calories
    d. For men, it is 2500 calories and for women, it is 2200 calories

    > Answer: a. The average BMR for women is 1400 calories, while the average BMR for men is 1800 calories. It is dependent on the individual's height, weight, and age.

4. What is least likely to be a comorbidity in obesity that may affect the individual's ability to exercise?

    a. Heart disease
    b. Osteoarthritis
    c. Lung disease
    d. Diabetes

    Answer: c. Each of these can be comorbidities seen in obesity that can impact the ability to exercise. Lung disease is least likely to be a comorbidity, although obese individuals will be shorter of breath and may wheeze with exercise.

5. In recommending aerobic training, what would be an acceptable range for the obese individual with regard to heart rate?

    a. 50 percent of maximal heart rate
    b. About 150 beats per minute
    c. At least 70 percent of maximal heart rate
    d. 20 percent above resting heart rate

    Answer: c. The recommendations for optimal aerobic exercise are at least 70 percent but below 94 percent of the maximal heart rate, which is determined by taking 220 beats per minute and subtracting one's age.

6. What is the main goal in managing the care of the obese patient when it comes to their exercise and weight loss goals?

    a. Prevention of additional weight gain
    b. Normalization of body weight
    c. Sustained weight loss over time
    d. Weight loss of 25 percent of initial body weight

    Answer: a. The main goal is to prevent additional weight gain with the reduction of and maintenance of weight loss being secondary. Normalization of body weight should not be the goal as this is often unrealistic; however, losses of 5 to 10 percent of body weight are usually recommended.

7. What is the recommended amount of exercise for the individual who is actively trying to lose weight?

   a. 20-25 minutes
   b. 30-35 minutes
   c. 45-60 minutes
   d. 60-75 minutes

   Answer: c. For actual weight loss, the recommended amount of exercise should be 45-60 minutes. It takes about 20-30 minutes of exercise to stop burning glycogen and start burning fat so this amount of exercise is generally considered the bare minimum for the start of fat burning.

8. In order to lose a pound a week in a weight loss program, what should the negative energy balance be per day for the overweight person?

   a. 100 calories per day
   b. 500 calories per day
   c. 1000 calories per day
   d. 1500 calories per day

   Answer: b. In order to lose weight at a rate of one pound per week, the obese person should have a negative energy balance of 500 calories per day, made up for by exercising more and eating less.

9. What is the main benefit of resistance training in overweight older adults?

   a. It will promote weight loss but will not improve metabolic parameters.
   b. It will promote weight loss and will improve metabolic parameters.
   c. It will not promote weight loss but it will improve metabolic parameters.
   d. It will not promote weight loss and will not improve metabolic parameters.

Answer: d. Resistance training by itself will not promote weight loss and will not improve metabolic parameters. It will help older individuals who do lose weight, however, preserve lean muscle mass.

10. In overweight people, what will be the recommendation for maintaining weight loss after it has been achieved?

    a. Continue calorie restriction without exercise
    b. Continue calorie restriction and exercise
    c. Stop calorie restriction and continue exercise
    d. Calorie restriction and exercise increase are not necessary after weight loss has been achieved

    Answer: b. In overweight people, there should be ongoing calorie restriction and continued exercise even after weight loss has been achieved.

CHAPTER 12: EXERCISE IN DIABETES

This chapter discusses type 1 and type 2 diabetes and the role that exercise has in the prevention and management of these conditions. Exercise is known to improve insulin sensitivity and to decrease the risk of developing type 2 diabetes. As you will see in this chapter, exercise is strongly beneficial in helping patients who already have type 2 diabetes. Individuals with type 1 diabetes will also benefit from exercise but need to take special precautions with regard to diet and insulin use while being physically active.

PREVENTION OF DIABETES WITH EXERCISE

It is well-known that people with diabetes will have an improvement in their disease process by engaging in exercise. Even so, this is one of the last things that doctors recommend for these types of patients. Recent research indicates that, in high risk populations, the type 2 diabetes risk can be reduced by 58 percent in individuals at high risk for the disease.

Research shows that type 2 diabetes is largely preventable with changes in lifestyle. Active people are more likely to be leaner, have lower fasting glucose levels, have enhanced insulin sensitivity, have low abdominal circumferences, and a lower risk of type 2 diabetes. This seems to also be the case in otherwise high-risk subjects. The predominant predictor of decreased diabetes risk is weight loss. For every kilogram, the risk decreases by 16 percent.

The conclusion is that type 2 diabetes can be preventable and that prediabetes is reversible. In fact, it takes 30 minutes of moderate activity at a minimum of three days per week for six months in order to reduce the prediabetic state. Insulin sensitivity can be reduced without a change in diet. The effect appears to be long-lasting, with a 42 percent decreased chance of getting type 2 diabetes after 14 years of follow-up.

Diabetics who exercise will have a reduction in blood sugar levels for up to two days after mild to moderate exercise. It is directly related to the duration and intensity of the exercise, the type of activity, and the pre-exercise diabetes management. About two hours after exercise, there seems to be an increase in the amount of glucose that goes into glycogen, which may account for the reduction in blood sugar seen after exercise.

Remember that muscle glycogen gets used up during exercise and must be replaced. This is likely why there is a reduction of glucose after physical activity. Because there are two mechanisms that build glycogen—one is insulin-dependent and the other is secondary to muscle contractions. The second method is independent of insulin. This effect starts at two hours after exercise and disappears about 48 hours after exercise. Again, little insulin is required for this to occur.

Those who regularly exercise will benefit from the acute effects of the last episode of exercise. They will also have physical changes resulting from repeated exercise participation. The skeletal muscles will have an increased responsiveness to insulin and improved basal blood glucose uptake. The proteins responsible for taking up and metabolizing glucose will increase and there will be an increase in the oxidative capacity of fat in the skeletal muscle. Insulin sensitivity and the ability to utilize glucose will be improved for up to a week afterward in those who exercise on a regular basis.

The use of regular physical activity (both aerobic and resistance training) will not only prevent diabetes but will decrease the incidence of diabetes-related complications to blood vessels. This is because there is always inflammation going on because of insulin-resistance and chronically high blood sugars. Aerobic training will slow the progression of or prevent the onset of diabetic nerve disease, will improve blood vessel wall function, and improve insulin production in type 2 diabetics who can still make insulin.

Managing Diabetes with Exercise

In order to have an improvement in diabetes with exercise, it should occur at least three days per week, separated by no more than 72 hours. This means that the exercise should be nonconsecutive. There should be at least 10-minute sessions of exercise up to the recommended time of 30 minutes a day. It can be low to moderate intensity and should take into account things like peripheral neuropathy (nerve disease) and arthritis. These two diseases may require non-weightbearing exercises like swimming or stationary cycling.

As with most exercise prescriptions, aerobic exercise is recommended the most. This is because this form of exercise is good for the heart and will decrease the blood sugar the most. Continuous moderate exercise at 30 minutes per day over eight weeks will increase the enzyme responsible for the synthesis of glycogen (called glycogen synthase). The longer the activity, the more glycogen is depleted so that potentially carbs need to be taken in order to prevent fatigue during longer exercises and to provide a source for energy in diabetics after glycogen has been depleted (which is about 20 minutes into the exercise).

Aerobic training increases the use of fat in the body. This has the effect of sparing the muscle glycogen stores and will result in a smaller decrease in blood glucose in diabetics. This means less adjustment in insulin dosing among diabetics who take insulin. For hard exercise, the use of carbohydrates and blood glucose is increased by this type of aerobic training. Fat oxidation is an important consideration when it comes to improving insulin sensitivity in overweight people.

Resistance training is also recommended for diabetics because it will improve muscle strength and endurance. It will change the body composition, decrease heart disease risk, enhance flexibility, and will increase the amount of insulin-sensitive muscle mass. It is recommended to be performed about twice a week (which is the same amount recommended for all individuals). The major muscle groups should be exercised with about 10 exercises done at 10 to 15 repetitions per exercise to nearly being fatigued.

Intense workouts will increase the glucose-raising hormones like epinephrine, which will possibly increase glucose levels temporarily. On the other hand, heavy workouts that involve weight training in diabetics will improve glycemic control and will improve insulin sensitivity in type 2 diabetics so it is still recommended. The activity of insulin has been found to increase by 48 percent after four to six weeks of moderate intensity resistance training performed five times per week, even with no change in aerobic capacity. Twice weekly resistance training done for four months will also similarly increase the action of insulin. This is associated with a loss of visceral fat, a reduction in fasting blood sugar, even though there is an increase in caloric intake in these individuals.

The greatest benefit for diabetics is seen in combined aerobic and resistance training. This is true, regardless of the type of diabetes. This combination will improve the action of insulin and will reduce the glycated hemoglobin levels or hemoglobin A1c levels, which are averages in the glucose in the system over the previous three months. Resistance training will also decrease the abdominal fat content compared to aerobic training alone.

Only about 39 percent of adults with diabetes engage in at least 30 minutes of exercise three times a week. This is compared to 58 percent of individuals without the disease. This is the case, in spite of the fact that exercise has a positive effect on the individual who has diabetes. Exercise is not only safe but is beneficial and blood sugars with exercise can be managed in a safe fashion.

Diabetic individuals may be concerned about upsetting the glycemic balance during exercise, resulting in too low or too high blood sugar readings during exercise. This is particularly a concern among insulin users. Prior activity does carry the risk of experiencing hypoglycemia (low blood sugar) during exercise, particularly in those who take insulin for their diabetes.

On the other hand, intense activity can raise blood sugar temporarily, although exercise after a meal can cause low blood sugar during exercise (because of high insulin levels after eating). Longer-acting and low intensity activities will result in a decline in blood sugar levels in all people who have diabetes, regardless of the type they have.

The risk of low blood sugar during exercise is low among diabetics who do not take medication for their disease. Even so, blood sugar monitoring is helpful before and after an activity in order to see what effect it has on the diabetes and blood sugar levels. Taking carbs during the activity is not necessary unless monitoring shows low blood sugars after the exercise. About 15 grams of sugar or carb per hour should be used until a more optimal amount can be determined through monitoring.

On the other hand, prolonged exercise has a greater potential to result in low blood sugars during and after exercise, especially in those who take oral medications for their diabetes or who take insulin. To prevent this, a simple carbohydrate should be consumed to counterbalance this problem. Another potential solution is to take less medication or less insulin when exercise is anticipated. Long-acting medications for diabetes have the greatest problem with causing low blood sugar during exercise. Short-acting oral drugs have less of an effect and those on diet control alone have little problem with hypoglycemia during exercise.

For diabetics who take short-acting insulin, they may need to decrease their insulin dose in order to prevent low blood sugars before planned exercises. There may need to be monitoring of glucose before, during, and after exercise with eating carbs and later reducing insulin dose in order to compensate for exercise. This is especially true if exercising while the insulin effectiveness is at its peak. Long-acting insulin should have less of an effect on the blood sugar levels during exercise.

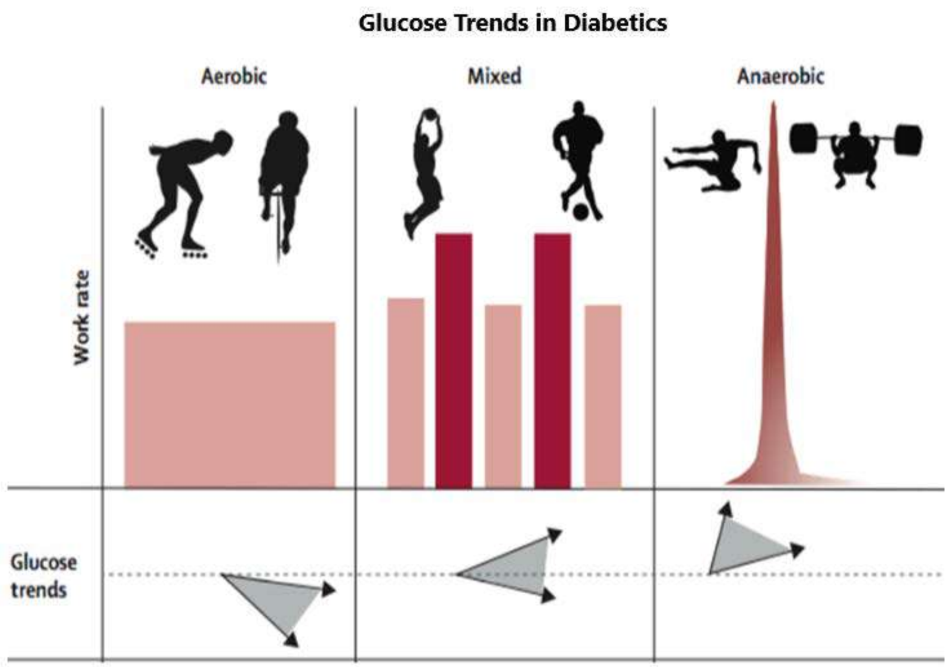
The bigger problem is the effect of low blood sugars after exercise, when the muscle and liver glycogen stores are at their lowest after an activity. This is especially true after intense training or repeated interval training. All of this is made worse by the taking of insulin or long-acting sulfonylureas (oral medications for blood sugar). This can be helped by taking in about 30 grams of carbs during or within thirty minutes after an exhaustive exercise program. Lower insulin doses might also be necessary.

If the pre-exercise glucose level is less than 100 milligrams per deciliter, some type of carbohydrate should be taken in before any activity is done. This is especially true for diabetics who take insulin or certain oral medications. It is less likely to be necessary for activities that last less than one hour. About 15 grams should be taken in before the exercise when the blood sugar is less than 100 milligram per deciliter. Blood sugars less than 250 milligrams per deciliter usually do not affect exercise so nothing special needs to be done and exercise can proceed with good hydration throughout.

TYPE 1 DIABETES AND EXERCISE

Diabetics with type 1 diabetes generally need to take insulin as they do not make their own insulin. Even so, there is no reason they should limit activities, such as strength training and aerobic exercise. Exercise can increase glucose uptake in the muscles by up to fifty times. Low blood sugars tend to occur in individuals who exercise longer than 45 minutes. There is a risk of low blood sugar for the first 24 hours after the exercise activity with the greatest risk of low blood sugar during sleep when exercise happens in the afternoon.

As mentioned, intense anaerobic or intense aerobic activity can increase the blood sugar during exercise that can last for several hours after the activity. For this reason, it may be helpful to take insulin in small quantities to correct this but any over-correction will have the potential to cause severe nocturnal hypoglycemia and possible death. Figure 28 shows the trends in glucose diabetic athletes:



While there are a lot of variation between athletes and their activity, the recommendations for type 1 diabetics are that if they start with a fasting blood sugar below 90 milligrams per deciliter, they should take in 10 to 20 grams of glucose before starting to exercise and wait to exercise until the blood sugar is greater than 90.

If the blood sugar is between 90 and 124 milligrams per deciliter, the diabetic can start exercising but should take in 10 grams of glucose before exercising. If the blood sugar is between 126 and 180 milligrams per deciliter, aerobic exercise can be started but anaerobic exercisers should know that the blood sugar may elevate during exercise.

If the blood sugar is above 182 but less than 270 milligrams per deciliter, exercise can be undertaken with the knowledge that it might go up if the activity is anaerobic. If the blood sugar is above 270, check blood ketones and, if mildly elevated, short exercise should be undertaken only. If high, exercise is not recommended. Mild to moderate aerobic exercise can be done if the urine or blood ketone levels are low.

Another strategy for intense exercise is to reduce insulin dose by 30 to 50 percent up to 90 minutes before aerobic exercise along with taking in around 30 to 60 grams per hour of carbs that are fast-acting during the sporting activity (when it is intense).

There are specific recommendations for total daily food intake in the exercising diabetic athlete. As per recommendations we've already talked about, 45 to 65 percent of the food should be carbs and 20 to 35 percent of the food should be fat. This leaves zero to 35 percent of the diet as protein, with higher protein intake recommended for those diabetics who want to lose weight. After exercise, about 20 to 30 grams of protein should be eaten to promote protein synthesis in the muscles.

Low glycemic index foods are the best choice before exercise, while high glycemic index foods should be taken in right after exercise in order to enhance glycogen recovery. These low glycemic index foods eaten a couple of hours before exercise seem to improve performance in type 1 diabetics compared to those athletes who take high glycemic index foods.

Diabetics should consider what type of liquid they should be drinking while exercising. Short-duration exercise (less than 45 minutes) should involve water if the blood sugar is above 125 milligrams per deciliter before the activity. Sports beverages will contain six to eight percent carbs and are helpful for long-duration exercises but have the potential to raise blood sugar levels. Milk-based drinks have carbs and proteins that can prevent delayed low blood sugar and can help in recovery. Caffeine will block the possible effects of exercise that lead to low blood sugar during exercise but might increase the risk of late-onset hypoglycemia (low blood sugar).

As for changing the insulin dose during exercise in the type 1 diabetic, these are the recommendations. Decreasing the short-acting insulin dose is probably only helpful in predictable activities done within two to three hours after a meal. A reduction in basal insulin dosing is not recommended unless there are serious increases in activity, such as a tournament that would last all day. Insulin should never be stopped before exercises. To combat nocturnal hypoglycemia, there should be a 50 percent reduction in bolus dose for the meal taken after the exercise along with the consumption of a low glycemic index snack at bedtime.

Key Takeaway

- Exercise can reduce the risk of developing type 2 diabetes but not type 1 diabetes.
- Type 1 and type 2 diabetics should still exercise as they will derive benefits against their disease process and complications of having the disease.
- Anaerobic exercise can increase blood sugar during exercise; however, other exercises will have a reduction in blood sugar during and after exercise, lasting up to 48 hours.
- Exercise in the diabetic should be avoided if the blood sugar is less than 90 milligrams per deciliter.
- The diabetic should take in complex carbs before exercise and simple carbs and protein after exercise.
- Type 1 diabetics, in particular, run the risk of having nocturnal hypoglycemia during the night after exercise, especially if the exercise happens in the afternoon.

QUIZ

1. In preventing type 2 diabetes, what is the best predictor of diabetes prevention?

    a. Increased exercise
    b. Low fat diet
    c. Weight loss
    d. Low sugar diet

    > Answer: c. Weight loss, when done by decreasing intake and increasing exercise, will be the best predictor of diabetes prevention, with a 16 percent reduction for every kilogram lost.

2. Exercise has been known to decrease the type 2 diabetes risk in high-risk individuals by about how much?

    a. 6 percent
    b. 12 percent
    c. 23 percent
    d. 58 percent

    > Answer: d. Exercise will decrease the risk of type 2 diabetes in high risk individuals by 58 percent.

3. What will not be positively affected in patients who exercise and who have or are at risk for diabetes?

    a. Prevention of diabetes
    b. Improvements in blood sugar
    c. Reduced complication risk
    d. Each of these is improved

    > Answer: d. Not only can diabetes be prevented by exercise, blood sugars will reduce in diabetes and the risk of diabetic complications will be reduced in patients who already have the disease.

4. You are recommending exercise for a diabetic. What is the minimum amount of exercise that should be done in order to have an effect on the diabetic process?
    a. 20 minutes twice a week
    b. 10 minutes three times a week
    c. 30 minutes three times a week
    d. 30 minutes five times a week

    Answer: b. The minimum should be 10 minutes three times a week, preferably spread out over the week with no more than 72 hours between exercise activities.

5. What form of exercise is considered the healthiest for the diabetic?
    a. Aerobic training
    b. Resistance training
    c. Flexibility training
    d. Balance training

    Answer: a. Aerobics has the advantage of enhancing the glucose uptake so as to reduce blood sugar levels and to have the best effect on the heart.

6. What is the recommended amount of resistance training for diabetics?
    a. 20 minutes per week
    b. Once a week
    c. Twice a week
    d. five times a week

    Answer: c. Resistance training is recommended for diabetics as it has positive effects on many diabetic parameters. It is recommended at twice per week.

7. Which type of diabetic will have the least issue with low blood sugars during exercise?

   a. The diabetic on long-acting oral medication
   b. The diabetic on short-acting oral medication
   c. The diabetic on diet alone for diabetes
   d. The diabetic on insulin

      Answer: c. The diabetic on diet alone for diabetes will have little problem with low blood sugar during exercise. The other diabetic patients will have more of a problem with low blood sugar during the exercise process.

8. About how much glucose or rapid-acting sugar and how long after exercise should be taken by a diabetic after intense exercise?

   a. 10 grams two hours after exercise
   b. 15 grams one hour after exercise
   c. 30 grams 30 minutes or less after exercise
   d. 45 grams right after exercise

      Answer: c. The goal in a diabetic should be 30 grams 30 minutes or less after exercise in order to prevent the low blood sugar (hypoglycemia) that can occur after an intense exercise activity and to replenish glycogen stores.

9. What should be the lower limit of acceptable blood sugar before starting to exercise in the type 1 diabetic?

   a. 60 milligrams per deciliter
   b. 90 milligrams per deciliter
   c. 120 milligrams per deciliter
   d. 150 milligrams per deciliter

      Answer: b. The diabetic with a blood sugar of less than 90 milligrams per deciliter should not exercise until their blood sugar is above this level.

10. Above what blood sugar level should the diabetic with type 1 diabetes check their ketone levels?

a. 150 milligrams per deciliter
b. 210 milligrams per deciliter
c. 270 milligrams per deciliter
d. 310 milligrams per deciliter

Answer: c. The blood sugar above 270 milligrams per deciliter doesn't mean that activity cannot be done; however, the ketone levels should be done and exercise avoided if the ketones are high.

Chapter 13: Exercise and Injuries

This chapter focuses on sports, exercise, and the various injuries athlete can experience. It starts with the topic of overtraining and the relatively common “overtraining syndrome” when exercising athlete simply exercises too much and burns out. Muscle injuries in the athlete and other orthopedic injuries, including stress fractures of the lower extremities, are covered. There are many types of orthopedic injuries the athlete can have, which are also discussed.

Overtraining

There are many reasons why an athlete will have performance difficulties while working out. Poor nutrition, poor choices of exercise, poor form, or overtraining can be related to this problem. When it’s due to overtraining, the more the athlete does, the worse the problem gets. Severe overtraining can lead to what’s known as overtraining syndrome. Mild overtraining can feel as though the athlete has influenza, with fatigue, feeling rundown, and having a hard time training.

Some of the typical symptoms of overtraining syndrome include the following:

- Elevation in resting heart rate—the heart rate at rest will be as much as 10 to 15 beats per minute above the normal resting heart rate for the individual athlete. This is particularly seen in anaerobically-trained athletes, while aerobically-trained athletes will see a decreased heart rate.
- Insomnia—the athlete will be tired but will be unable to sleep, particularly on days that the athlete has been training.
- Emotional changes—overtraining has been shown to decrease the level of motivation, lower self-esteem, and can lead to depression.
- Muscle soreness—this is especially seen in weight lifters but can be seen in all athletes. The muscles will be sore for days rather than for just a few hours after a

workout. The muscle soreness can be in muscles that haven’t actually been trained.

- Poor performance—the goal of training is to enhance performance so, if the performance is dropping while training, this is a sign of possible overtraining syndrome.

As we have already discussed, the goal of training is to increase performance over time. These increases are achieved by doing more and through periods of activity plus rest in order to build muscle mass. Overtraining involves excessive training that leads to decreased performance rather than increased performance. As mentioned, this is accompanied by fatigue, low mood, and various neurohormonal changes in the training athlete.

There is a difference between functional overreaching, nonfunctional overreaching, and overtraining syndrome. Functional overreaching involves short-term excesses in training that actually increase performance when proper rest is taken into account. Nonfunctional overreaching takes weeks to months to occur and will result in poor performance and loss of training time as the athlete must rest to resolve their problem. Overtraining syndrome takes months to occur, resulting in serious performance decreases that can end the athlete’s career.

The symptoms can involve alterations in the parasympathetic or sympathetic nervous systems. Parasympathetic nervous system overactivity can cause fatigue, depression, and motivation issues. Sympathetic overactivity can cause insomnia, irritability, tachycardia, hypertension, restlessness, and agitation. Other symptoms include anorexia, weight loss, poor concentration, sore muscles, poor sleep, and anxiety. Parasympathetic overactivity is more commonly seen in aerobic sports, while sympathetic overactivity is most commonly seen in anaerobic sports.

Recent research on overtraining syndrome suggests it is not just the physical overtraining that leads to the problem and its ultimate recovery. There appears to be a strong component of stress and psychological factors that play a role in getting this disorder.

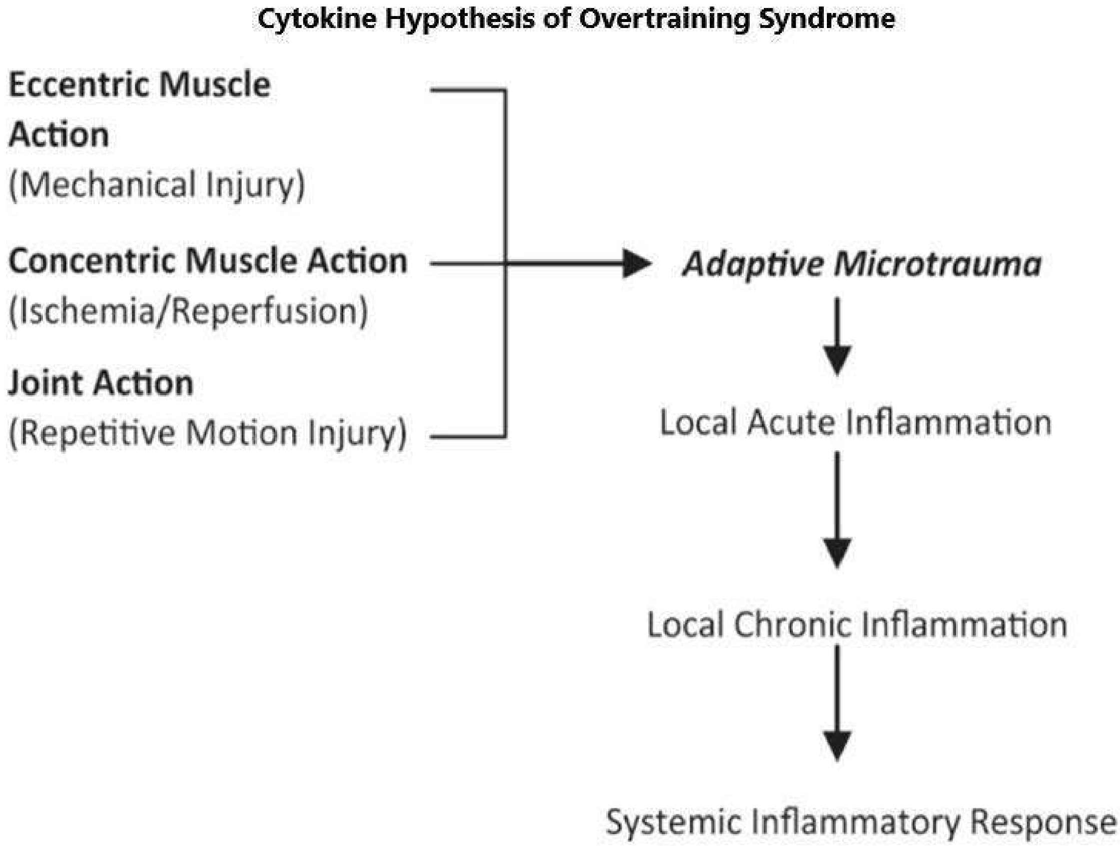
The actual development of overtraining syndrome is extremely rare, although the prevalence and incidence are not completely known. Nonfunctional overreaching syndrome is seen in about 60 percent of elite runners and about 33 percent of nonelite runners. Swimmers, too, can over-train, with an estimate of about 35 percent of high school swimmers having this problem. Interestingly, the risk of nonfunctional overreaching syndrome is higher in athletes training in individual sports, low physically-demanding sports (such as golf), women, and elite athletes. Athletes in team sports have a decreased risk of this disorder.

There has been a great deal of research on what causes overtraining syndrome and there are many theories about how it occurs. Here are some ideas about what causes this problem:

- Glycogen hypothesis—it is believed that low glycogen stores on a chronic basis lead to overtraining syndrome. While low glycogen stores can cause decreased performance, this does not account for all of the problems and can still develop in athletes with normal glycogen stores.
- Central fatigue hypothesis—it is believed that there is increased tryptophan uptake in the brain, leading to mood symptoms and increased serotonin levels. Supporting this theory is that serotonin reuptake inhibitors that increase serotonin will decrease performance. The problem with this is that it is difficult to directly measure serotonin levels in the brain. Things like fatigue and mood can also have many other influences; this theory does not explain all of the athlete's symptoms.
- Glutamine hypothesis—the theory is that decreased glutamine in the body causes immune dysfunction and increased risk of infection. Glutamine is necessary for healthy immune cell function. There is a decrease in glutamine after exercise; however, supplementing with glutamine does not fix this problem and this does not account for all of the symptoms.
- Oxidative stress hypothesis—increased oxidative stress in the cells can cause fatigue and muscle damage. This is supported by the finding of resting markers of oxidative stress are higher in overtrained athletes. Increased numbers of reactive

oxygen species will lead to muscle damage seen in these athletes. The problems are that it does not explain all the symptoms and that there is little research available on this theory.

- Autonomic nervous system hypothesis—this is the theory that is based on the idea that parasympathetic predominance is seen overtrained athletes (training aerobically). There is a decreased beat-to-beat variability in heart rate seen in the morning upon awakening in overtrained athletes. This does not account for all symptoms and is disputed in some studies.
- Hypothalamic hypothesis—this is believed to be related to dysregulation of the hypothalamus and the various pathways linked to the endocrine system. Overtrained athletes can have changes in cortisol, adrenocorticotropic hormone, testosterone, and other hormone levels. Proof of this theory is the activation of the hypothalamic-pituitary-adrenal axis in athletes compared to controls. This too does not account for all of the symptoms and there are other factors that can influence the endocrine axes said to be abnormal in these athletes.
- Cytokine hypothesis—the basis of this is that inflammation and cytokine release causes many of the symptoms of overtraining. This is a unified theory that explains why overtraining syndrome develops, including the fact that cytokines regulate illness and behavior together. With excessive training, there can be a systemic inflammatory response that results in total-body pathology. There are, however, no good studies proving this hypothesis. Figure 29 explains this theory:



In fact, these different theories all have some positive and negative aspects, with the cytokine hypothesis explaining most of what occurs in overtraining. Decreased glycogen, increased tryptophan uptake, alterations in the hypothalamic-pituitary-adrenal axis, and muscle soreness can all be explained by this hypothesis.

Most athletes with overtraining syndrome present with an unexplained problem with underperformance. This is a clinical diagnosis and there are no tests that can identify it. By history, the person will have mood disturbances, weeks or months of underperformance despite rest, and no other explanation for the problems. In looking for other things that might explain underperformance, the things that must be looked at include the following:

- Asthma or hyperreactive airway disease
- Adrenal disease
- Thyroid disease

- Diabetes mellitus or diabetes insipidus
- Iron deficiency
- Infection
- Malnutrition
- Mood disorder

An assessment of the athlete's nutritional history should occur along with an assessment of the athlete's energy expenditure. If there has not been a period of rest in order to recover, overtraining syndrome cannot be diagnosed. If it takes longer than three weeks without recovery, then overtraining syndrome can be diagnosed.

If there is the diagnosis of functional overreaching, the treatment is to balance training better along with appropriate recovery. The only treatment for nonfunctional overreaching and overtraining syndrome is relative rest, starting with 5 to 10 minutes of activity and building until one hour of training is tolerated. There is a significant psychological overlay with this syndrome so a sports psychologist may be necessary in order to fully recover from the problem.

Muscle Injuries

Muscle injuries are extremely prominent in athletes and nonathletes alike. The biggest problem is that it takes a relatively long period of time to recover from these types of injuries, during which time the athlete's performance can suffer. Most of these types of injuries come from overstretching of or trauma to the muscle itself. While many trainers advocate stretching before an exercise program and warming up, there is no evidence that this actually works to reduce muscle injury.

Skeletal muscle makes up to 50 percent of the body weight in men and as much as 35 percent of the body weight in women. Weightlifters can have up to 65 percent of body weight as muscle. Half of all muscles are type I (slow-twitch) fibers, while the other half are type II (fast-twitch) fibers. Fast-twitch fibers can become slow-twitch fibers through training but the reverse cannot happen. Isometric contraction involves no change in the muscle size, while concentric contraction involves shortening of the muscle. Eccentric contraction involves stretching of the muscle because the force is less than the resistance to the force. The types of injuries seen depend on the type of muscle contraction.

About 10 to 50 percent of all injuries to muscle come from sporting activities. The three most common muscle injuries seen in athletes include the gastrocnemius, quadriceps muscle, and hamstring muscles. Each of these muscles crosses two major joints and are susceptible to the forces of acceleration and deceleration.

There are several ways to classify muscle injuries. They can be acute (occurring within the previous three weeks) or chronic. They can be extrinsic (like external bruises) or intrinsic (like strains and muscle tears). Muscle bruising comes from direct trauma to the muscle, affecting other tissues. Muscle dysfunction doesn't directly attack the muscle structure and includes things like compartment syndrome (external swelling around the muscle), fatigue of the muscle, and muscle cramps.

Muscle injury severity can be classified as well. A type I injury is a muscle strain that affects less than five percent of fibers and comes from excessive stretching. Type II injuries involve muscle tears of between 5 and 50 percent of the muscle fibers. Type III injuries are complete tears of the muscle so that there is an obvious defect.

Exactly what happens in a muscle injury is exactly the same, regardless of the injury. There are three stages to the injury and repair process. It starts with the destruction phase. This involves bruising and bleeding from ruptured muscle fibers and inflammation of the muscles. Relaxed muscles will suffer more from bruising because the force will be transmitted through more muscle layers. Bruises tend to affect the muscle body, while strains affect the junction between the muscle and tendon.

After the destruction phase has diminished, effective repair of the injured muscle can begin. This involves regeneration of the broken muscle fibers and formation of scar tissue to heal the muscle tissue. There are satellite cells beneath the basal lamina of the muscle that are laid down in fetal development. These cells respond to injury by proliferating and turning into myoblasts. They help regenerate muscle tissue—an effect that diminishes with age.

The scar tissue formed in the muscle is a layer of connective tissue that forms immediately after the trauma and strengthens over time. Fibroblasts infiltrate in order to make the scar tissue. It becomes strong enough after ten days post-injury so that, if another injury happens, it happens not at the connective tissue layer but in the adjoining muscle tissue (near the scar). Sometimes the scar tissue becomes very large and fibrous, impacting the mobility of the muscle.

The first twenty-four hours after the muscle injury is especially critical to healing. Remember the PRICE protocol, which stands for protection, rest, ice, compression, and elevation. These things are the most crucial to muscle healing. Analgesics like ibuprofen and acetaminophen have short-term value but they can impair the healing process and may reduce the ability of the muscle to function.

Using the muscle too early can increase scar tissue formation so that there is more difficulty in getting enough circulation to the muscle. This means that braces may be necessary to rest and immobilize the muscle. While this is helpful, it should not be prolonged over more than a couple of days as it can cause stiffness of the joints and muscle weakness. Some type of mobilization should occur within three to four days after the injury—starting with passive movement and warming up to active movement. Mobilization helps the circulation in the muscles.

The major complication of a muscle injury involves an enlargement of the hematoma or blood clot in the muscle, which can become encapsulated or can impede the circulation to the muscle. Infection at another site or at the level of the injury can lead to pus formation and infection, which may need to be surgically drained. The surrounding epimysium or muscle fascia can be injured, resulting in the muscle tissue spilling out of its normal area of function so that pain and impairment can occur.

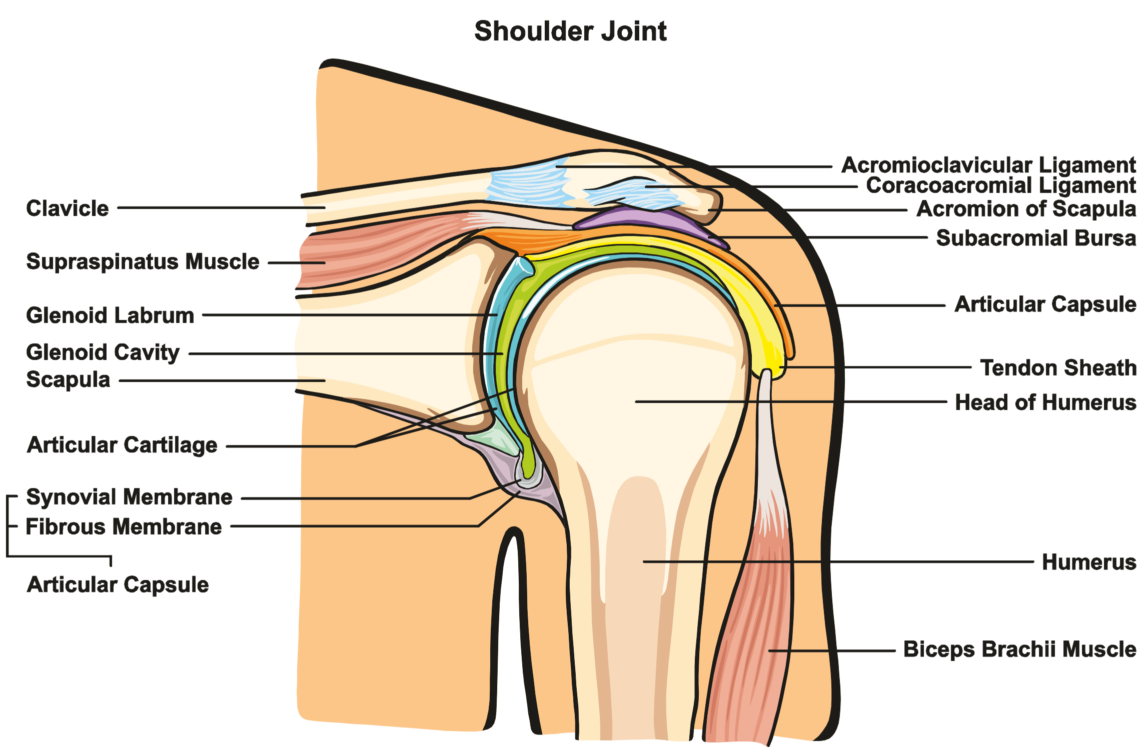
While stretching and warmup of the muscles has been believed to be helpful in preventing muscle injuries, it does not actually help reduce the incidence of muscle injuries. On the other hand, strengthening of certain muscle groups over time does seem to decrease the rate of injuries seen in athletes.

ORTHOPEDIC INJURIES

There are many injuries that can happen to the athlete as part of overuse, training injuries, or competition injuries. In this section, we will discuss a few of the more common injuries the athlete can develop.

SHOULDER TENDONITIS

Shoulder tendonitis is an overuse injury commonly seen in tennis players, baseball players, and swimmers. It results from repeated overhead motion of the shoulder. It is felt at the tip of the shoulder with the pain radiating down the athlete's arm, made worse by lifting the arm above the level of the shoulder. It can be intermittent or continuous. Figure 30 shows the anatomy of the shoulder:



As you can see, the shoulder joint involves a ball and socket. The upper arm bone is the humerus, with the rotator cuff muscles being the teres minor, subscapularis, infraspinatus, and supraspinatus muscles. There are friction-reducing membranes called bursae that protect the joint from friction. When the arm is raised, the archway of bone and ligament become compressed against the bursa and the tendons attaching arm muscles and shoulder muscles. Doing this repetitively results in inflammation of the bursa and tendons.

Tendonitis happens when one of the rotator cuff tendons becomes irritated, torn, or inflamed. The pain can last just a few days but can become chronic in nature. There are three types of shoulder tendonitis:

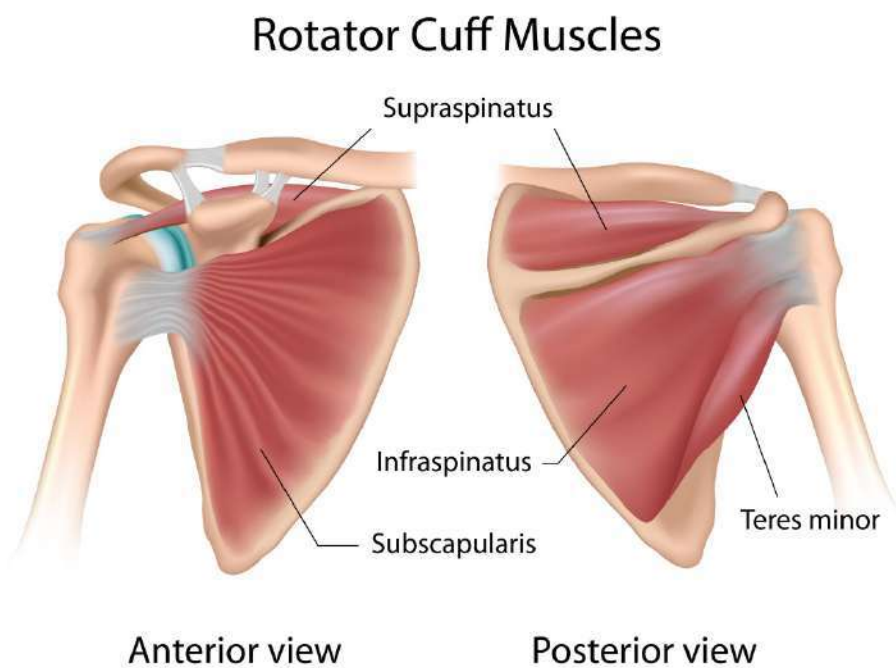
- Overuse tendonitis—this happens with repetitive stress and leads to irritation, fraying, or bruising of the tendon, leading to joint weakness.
- Calcific tendonitis—this happens when the tendon is inflamed for so long that it results in a buildup of calcium within the tendons of the rotator cuff, leading to pain, loss of strength, and decreased motion.
- Rotator cuff tear—this is severe tendonitis that happens when the tendon is degenerated, frayed or torn in a fall or other injury. The pain is more severe and there can be loss of normal movement.

Things that lead to this type of injury are repetitive overhead motion, weakness of the muscles, poor technique, overtraining, prior injuries, and laxity of the shoulder joint. Treatment for this problem include decreased repetitive motion, ice, anti-inflammatory medications, cortisone injections, and physical therapy to the affected shoulder.

For the athlete wanting to return to sporting activities, rest should happen with minimal overhead activities until the pain resolves. Changing the degree of angle of throwing (such as sideways throwing) with adequate warmup can help. Swimmers should try strokes that do not involve repetitive motion of the arm above the shoulder until the tendonitis heals.

ROTATOR CUFF INJURIES

As mentioned, the shoulder joint is stabilized and moved by the rotator cuff muscles that attach from the scapula to the humerus. Figure 31 shows the anatomy of the rotator cuff:



These four muscles surround and stabilize the shoulder joint by attaching the scapula to the humerus. The tendons lie just outside the joint capsule and the muscles help the athlete lift the arm, reach overhead, and do things like swim, play tennis, and throw a ball overhead. An acute injury, such as a fall or lifting a weight, will tear the rotator cuff immediately. Lifting the arm will cause increased pain in the outer aspect of the shoulder. Degeneration can also lead to a rotator cuff injury. Some of these injuries need surgical repair, while others cannot be repaired. Surgery can both heal the injury and relief pain.

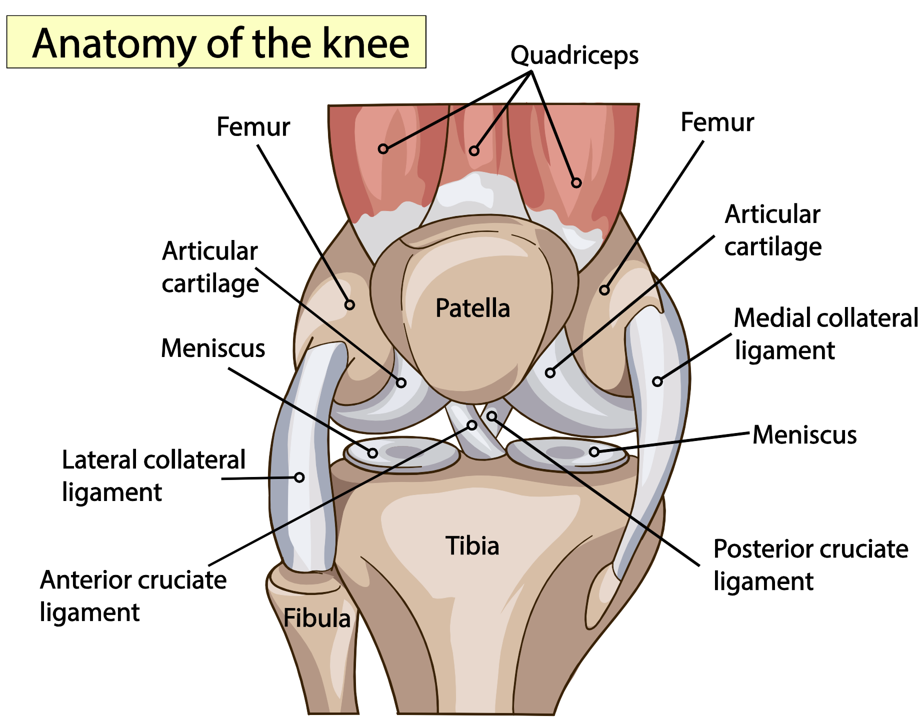
The typical symptoms seen in a rotator cuff tear is shoulder pain that can occur at night and weakness when raising the arm up. While weakness can define the injury, an MRI (magnetic resonance imaging test) is the most effective way to diagnose the injury.

Partial tears are best diagnosed with an MRI. It can be repaired surgically or treated with physical therapy. In surgery, holes are made in the humerus so that the tendon can be attached surgically to the bone.

Small tears in the rotator cuff are much more easily repaired surgically but, with large tears or old tears, the prognosis isn't as good. A tear that lasts several months before surgery has the least likely chance of healing. While there is pain after surgery, the pain is generally worse before surgery. The major complications of this type of surgery include shoulder stiffness, loss of range of motion, and degenerative arthritis of the shoulder joint.

ACL Tear

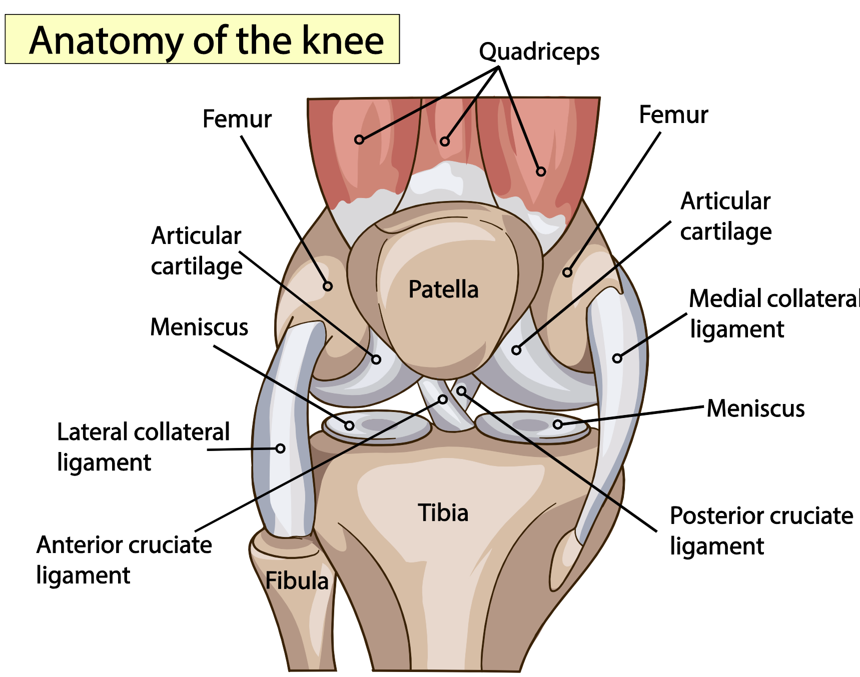
ACL stands for anterior cruciate ligament. This is one of several major ligaments in the knee. There are several ligaments, including the posterior cruciate ligament, the medial collateral ligament, and the lateral collateral ligament. Of these, the ACL is the most common knee ligament to be injured in a sports injury. Figure 32 shows the basic anatomy of the knee and these ligaments:



Each of these ligaments helps to stabilize the knee joint. The two collateral ligaments give stability to the sideways mobility of the joint. The medial collateral ligament is on the inner side of the knee joint, while the lateral collateral ligament is on the outer side of the knee joint. The ACL keeps the tibia from sliding forward with respect to the femur (the thigh) and allows for twisting, pivoting, and jumping in sports. The PCL keeps the tibia from sliding backward relative to the femur.

The most common way to injure the ACL is to have a sudden stopping of the foot while quickly twisting the knee. The body rotates toward the opposite side of the body. This is seen in sports like basketball, lacrosse, soccer, and football. In some of these sports, there are cleats that prevent slippage of the foot causing a majority of the stress to be transferred to the ACL. Skiers can get this injury by sitting back on the ground while falling, shifting the weight of the body backward. When the force is too great, the ligament tears.

The major symptom seen in the ACL tear is a loud pop or the sensation of a pop in the knee. There is generally an immediate sensation of knee instability and the “giving out” of the knee. There is immediate swelling of the knee as it bleeds inside the knee over a couple of hours. Pain and ambulation become difficult. Figure 33 shows what happens in an ACL tear:



The menisci (to be discussed later) are the fibrous cartilaginous shock absorbers of the knee. These can also be injured as the knee partially dislocates, causing compression of the menisci. Either meniscus can become torn in the process. The articular cartilage, which covers the joint surface, can also be damaged with an ACL tear. This will ultimately lead to arthritis of the knee joint.

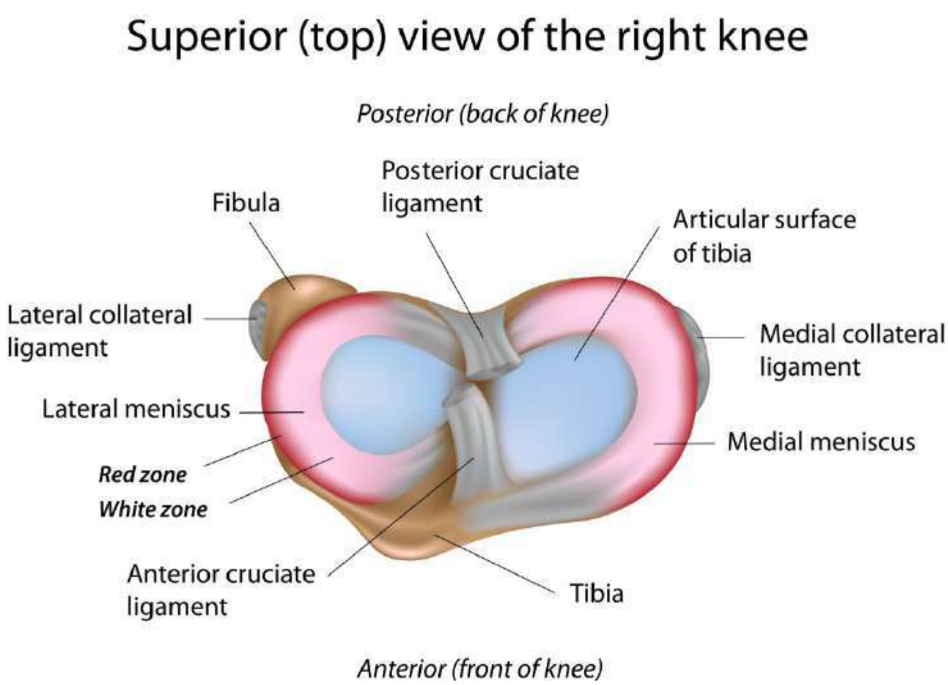
The main treatment for an ACL tear is initially rest and ice with compression of the knee. Splints and crutches may be necessary to ambulate and keep the knee stable. The diagnosis can be made clinically in many cases, although some individuals require an MRI.

While some individuals can get by without their ACL, the knee will always be unstable. This problem can also lead to damage to other knee structures. Arthritis can result from longstanding ACL dysfunction. For these reasons, the young athlete probably needs to have some type of treatment for an ACL tear. The younger the athlete, the more likely it is for the torn ACL to require surgical repair with twenty-five years of age being the age where ACL surgery isn’t always recommended.

Surgery is done six weeks after the injury, which is why the athlete with an ACL tear cannot get better quickly. Surgery is further delayed if there is another injury along with the ACL injury. The surgery often requires some type of ligament or tendon graft to ensure the creation of a strong ACL joint. Some athletes need revision surgery at a later date.

KNEE MENISCUS INJURIES

The knee menisci are two crescent-shaped cartilage pieces that lie between the femur and the tibia of the leg. There is a medial and a lateral meniscus. These will dissipate the forces on the surrounding articular cartilage of the knee. In fact, they prevent the wearing down of the articular cartilage, which can lead to osteoarthritis of the knee. Figure 34 shows the menisci of the knee:



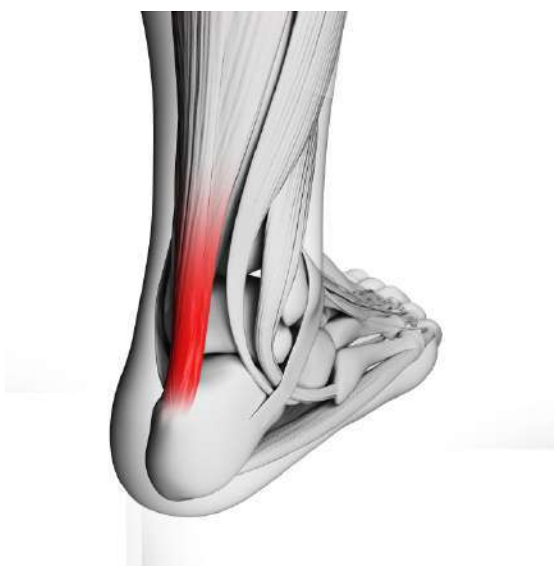
The injury can involve minor fraying of the meniscus or can involve torn pieces of the meniscus or even missing pieces of the meniscus. The injury can stem from a twisting or pivoting motion of the knee or from degeneration of the meniscus over time. The main symptoms are pain on one or both sides of the knee with swelling of the knee that is worse with activities. A sense of locking of the knee or “catching” of the knee can occur. Any type of twisting or lateral movement of the knee will make the pain worse.

The nonsurgical management of an ACL tear involves modification of activities, particularly twisting and deep squatting involve with the knee. Weight loss, intermittent ice or heat application, physical therapy, and oral anti-inflammatory medication can be used to treat this problem without surgery. Some athletes respond to injections of cortisone, platelet-rich plasma, or hyaluronic acid can lubricate the joint so as to facilitate the cushioning process. Knee braces can also help.

Some athletes require surgery to treat this problem. There are three main surgical options. The first is a meniscectomy (or meniscus trimming) in which the torn part of the meniscus is trimmed back. This is the procedure done about 90 percent of the time. Meniscus repair is done in younger athletes along with repair or reconstruction of other aspects of the knee. A meniscus transplant is reserved for people who have already had a meniscus trimming performed and have ongoing problems with the knee.

ACHILLES TENDON INJURIES

The Achilles tendon is the major tendon connecting the back of the calf to the heel. The calf is made by the soleus muscle deep within the calf and the large outer gastrocnemius muscle. When these muscles contract, they cause plantar flexion, or the pointing down of the foot at the ankle so as to rise up onto the toes. This motion is important to climbing, jumping, and sprinting. The Achilles tendon can degenerate over time, leading to weakening of the tendon. When the tendon is injured and heels, it can form scar tissue as the tendon is repaired. This can lead to nodules formed within the tendon. These nodules lead to Achilles tendinosis. Figure 35 shows the anatomy of the Achilles tendon:

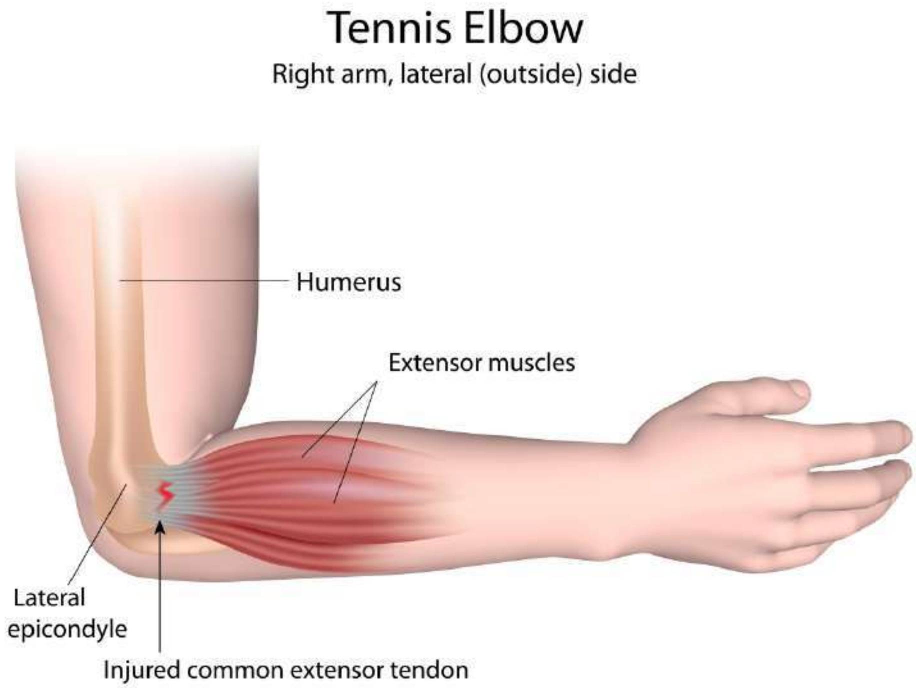


Athletes can get a spontaneous rupture of their Achilles tendon, usually between 20 and 40 years of age. It is more commonly seen in men and occurs when pushing forcefully off the foot in things like tennis, basketball, racquetball, and squash. The athlete will feel a pop or snap in the back of the ankle, leading to pain in the back of the ankle and the ongoing weakness of the ankle. After the initial pain, there is less pain but a gap can be felt in the back of the ankle. The diagnosis is usually completely clinical.

The treatment options are nonsurgical or surgical in nature. An equinus cast with a downward pointing of the ankle can be used for eight weeks in order to heal the Achilles tendon. There is a higher rate of rupturing the tendon again with this treatment and there is less strength in the tendon compared to a surgical option. Surgery involves sewing the torn ends of the Achilles tendon together with a zero to four percent rate of re-rupturing the tendon after surgery. The tendon tends to be stronger after surgery when compared to non-surgical options. Even with surgery, it takes six months post-surgery in order to return to sporting activities.

Tennis Elbow

This is medically referred to as lateral epicondylitis. It is pain on the outer aspect of the elbow, often seen in tennis players. Tennis elbow is an overuse injury that develops when the athlete lifts the wrist repeatedly, particularly because it is the tendon of the muscle involved in this action that becomes inflamed. Things that contribute to this problem include muscle weakness, excessive gripping of the racquet, improper tennis equipment, or poor technique. Figure 36 shows what this problem looks like:



The pain tends to come on gradually and improves with rest. In treating this injury, the athlete may need to scale back practice or rest the affected forearm. Ice to the affected area before and after exercise can help and stretching the forearm can prevent stiffness. There are "tennis elbow" braces that apply a counterforce on the affected forearm. Cortisone shots or anti-inflammatory medication can also help reduce pain and aid healing. Physical therapy is aimed at strengthening the forearm muscles.

Tennis players can improve by using a light weight racquet and by changing their stroke to make use of the backhand stroke less. Before a game or before practice, warming up the joint can help reduce the degree of pain. Stretching and ice can help after the game as well to reduce the amount of inflammation in the forearm.

STRESS FRACTURES

A stress fracture can involve an actual crack in the bone or bone bruising brought on by overuse and repetitive injury to the lower extremities. It is seen in runners and athletes who are on their feet a lot and is often seen when there is a change or addition of a new workout routine. The most common places for a stress fracture include the second or third metatarsals of the foot, the calcaneus (the heel bone), the fibula (the outer bone of the lower leg), the talus (in the ankle) and the navicular bone in the midfoot.

These are overuse injuries that stem from repetitive forces acting to create microscopic injury to the bone. The athlete most prone to this is one who has a sudden increase or change in physical activity. It can be seen in non-athletes who walk repeatedly on uneven surfaces. Even new shoes can contribute to getting a stress fracture. Individuals with osteoporosis or other mineral deficiency can have a greater chance of fractures. This means that women with the female athlete triad will have a greater chance of having this type of injury.

The main symptom seen is pain in the foot or ankle that is made worse by doing a weight-bearing activity. There can be swelling on the top of the foot or the outside of the ankle as well as tenderness to touching the affected area and possible bruising of the foot or ankle. The diagnosis is made with an x-ray that often doesn't show the fracture right away. For a more immediate diagnosis, an MRI can be done of the affected area.

Most stress fractures can be treated without surgery. Modification of activity for six to eight weeks can allow a stress fracture to heal. Protective footwear can be used to protect the foot until it heals. Casting of the foot is often done with navicular, fifth metatarsal and talus fractures. Screws or plates can be used in the surgical management of fractures that are not healing well on their own.

Key Takeaways

- There are different degrees of overtraining that can affect the athlete, the most severe of which is overtraining syndrome.
- There are many theories behind overtraining syndrome that partially explain what is happening in the athlete who suffers from this.
- Muscle injuries can range from bruising of the muscle to actual muscle tears.
- There are several orthopedic injuries of the shoulder, elbow, lower leg, and knee that can affect the athlete. Many of these are overuse injuries although some are secondary to an acute injury.
- Orthopedic injuries can be treated with rest, exercise modification, and sometimes surgical intervention.

QUIZ

1. What is least likely to be a symptom of overtraining?

    a. Depression
    b. Decreased respiratory rate
    c. Insomnia
    d. Decreased performance

    Answer: b. These are all symptoms of overtraining syndrome; however, changes in respiratory rate are not seen. There is generally an increased heart rate seen in anaerobically-trained athletes and a decreased heart rate seen in aerobically-trained athletes.

2. What is an example of parasympathetic overactivity seen in athletes who over-train?

    a. Insomnia
    b. Irritability
    c. Anxiety
    d. Fatigue

    Answer: d. There can be sympathetic or parasympathetic overactivity seen in athletes who over-train. The parasympathetic overactivity can lead to fatigue, depression, and lack of motivation. The others are considered sympathetic overactivity issues.

3. Which athlete will have the least likely chance of having overtraining syndrome or nonfunctional overreaching syndrome?

    a. Swimmers
    b. Golfers
    c. Soccer players
    d. Elite runners

    Answer: c. Individual-sport athletes, golfers and others in low-energy sports, and swimmers will have a higher risk of overtraining, as well as elite athletes. The athlete involved in team sports will have a lesser chance of overtraining or nonfunctional overreaching syndrome.

4. What theory on overtraining helps to explain the decreased heart rate variability seen in overtrained athletes after awakening?

    a. Glutamine hypothesis
    b. Oxidative stress hypothesis
    c. Hypothalamic hypothesis
    d. Autonomic nervous system hypothesis

    Answer: d. It is believed that overactivity of the parasympathetic nervous system and underactivity of the sympathetic nervous system explains the variation in heart beat-to-beat variability seen in athletes who overtrain.

5. What test will prove the diagnosis of overtraining syndrome?

    a. Free cortisol level
    b. Thyroid function testing
    c. Serum cytokine levels
    d. There is no test for this disorder

    Answer: d. There is no test for this disorder. This isn't to say that tests can be done; however, the tests used will look for other disorders rather than to diagnose overtraining syndrome.

6. What is not a major muscle affected by muscle injuries in sports and with athletes?

    a. Gastrocnemius
    b. Hamstrings
    c. Deltoid muscle
    d. Quadriceps muscles

    Answer: c. The top three muscles affected by muscle injuries are the gastrocnemius, hamstring muscles, and quadriceps muscles.

7. How long should the athlete immobilize a muscle that has become injured in the muscle itself?

    a. one day
    b. two days
    c. seven days
    d. two weeks

    Answer: b. Just two or three days is the maximum number of days that a muscle should rest after an injury. After that, passive immobilization should be instituted so as to enhance muscle circulation and to prevent joint and muscle impairment after the injury.

8. How long should the athlete stretch the leg muscles to prevent muscle injuries?

    a. 5 minutes
    b. 10 minutes
    c. 20 minutes
    d. Stretching does not help prevent injuries

    Answer: d. While it is frequently done by athletes, stretching does not actually help prevent muscle injuries. Strengthening, however, does seem to prevent injuries to muscles.

9. What is the best test to make the diagnosis of a torn rotator cuff in the shoulder?

    a. Shoulder x-ray
    b. CT scan of the shoulder
    c. Clinical exam
    d. MRI of the shoulder

    Answer: d. While a clinical exam can help in the diagnosis, it takes an MRI of the shoulder to help identify partial tears in particular, which can be difficult to diagnose.

10. What ligament is most commonly injured in the knee joint?

   a. Lateral collateral ligament
   b. Medial collateral ligament
   c. Anterior cruciate ligament
   d. Posterior cruciate ligament

      Answer: c. The anterior cruciate ligament or ACL is the most commonly injured ligament in the knee joint by athletes.

SUMMARY

This course covered the basic principles of exercise and sports physiology for trainers, doctors, and other practitioners interested in how the human body exercises and what happens during exercise. True exercise only happens when there is coordination of the brain, respiratory system, cardiovascular system, and muscles—each contributing to the act of exercising and sports participation. We looked at the components of the body necessary for exercise and the established ways that athletes can maximize their exercise performance. We also discussed were the interactions between disease states, certain disabilities, and exercise and the ways to manage injuries and illnesses related to training.

Chapter one introduced the topic of skeletal muscle anatomy and physiology, both at rest and with exercise. Essentially no exercise can happen without the coordination of skeletal muscle, which receives input from the nervous system in order to function. Muscle tissue stores energy at rest and utilizes that energy at a rapid rate, especially during intense exercise. How muscles function and how they adapt to exercise was also covered.

Chapter two covered the anatomy and physiology of the heart as well as the way that the cardiovascular system responds to exercise. Similar to the statement that no exercise can happen without muscle function, the heart and the blood vessels supplying muscle tissue are also crucial to the participation by an athlete in any sporting activity. Most exercise—in particular aerobic activities—involves the proper response of the heart and blood vessels to the act of exercising the human body. There is a great deal of stress placed upon the heart in any form of sporting activity, making it a very important organ of study for the exercise physiologist.

Chapter three focused on the respiratory system, what it involves, how it works, and how it responds to activity. The anatomy of the lungs was covered, including how they take in oxygen and how they function in order to exchange oxygen and carbon dioxide. In addition, the chapter covered the way the two gases are transported in the body and how the reverse exchange happens at the tissue level. The way in which exercise influences the respiratory system was also covered.

Chapter four discussed the role of anaerobic exercise, which is exercise that does not require oxygen. One of the main types of anaerobic exercise is resistance training, involving a wide range of activities designed to tone or build muscles. Resistance training or “strength training” is not just for bodybuilders and has a role in every person’s exercise program. Types of resistance training and the way the body adapts to resistance training were discussed.

Chapter five was about the basics of aerobic exercise, the types of exercise involved in aerobic exercise, and the benefits of cross-training for an athlete. The term “aerobic exercise” translates to “exercise with air,” implying that this is a type of activity that makes use of oxygen. Indeed, aerobic metabolism fuels aerobic exercise. There are many benefits to aerobic activities that differ from those seen in anaerobic exercise. Cross-training involves switching up activities in order to maximize performance, reduce injuries, and lessen boredom.

Chapter six talked about exercise in extremes of temperature and altitude. Many athletes cannot exercise in temperate weather all the time and need to adjust their workouts to make accommodations for extreme cold or hot weather. There are specific bodily responses to exercising in these extremes that need to be taken into account when working out. The chapter also talked about hot yoga, in which individuals practice yoga under conditions of high heat and humidity. High altitude exercise has received a great deal of attention among elite athletes, who train at high altitudes to help them perform better at low altitudes; this was another component of this chapter.

Chapter seven focus was exercise training or sports training. One of the goals of the sports physiologist is to determine the best exercise prescription for the athlete starting or changing their exercise program. When aiding a person with starting an exercise program, there are certain questions that must be asked and specific ways to start these types of programs. Before, during, and after training, it is a good idea to determine the athlete’s body mass index (BMI) and body composition in order to follow their progress.

In addition, some will want to use various ergogenic aids in order to maximize their performance, so this was discussed in this chapter.

Chapter eight covered the basics of the nutrition of carbohydrates, protein, and dietary fats. There is significant misinformation about these different types of foods and the role they play in athletics. There are many fat diets out there and many athletes have specific ideas about what foods they should eat or not eat before, during, and after training. This chapter offered solid information about the different types of macronutrients in the diet and how they are used in athletics as fuel sources for different types of training.

Chapter nine focused on age and gender considerations in training and exercise. Children often start athletics at an early age, thus developmental considerations must be included in their training and exercise programs. Exercise clearly benefits children of all ages but their exercise programming must be weighed against their developmental issues. When it comes to exercise, much of the emphasis is on the male athlete so this chapter dealt with the female athlete and her unique issues and concerns. The problems, challenges, and advantages related to being athletic as an older adult were also discussed.

Chapter ten talked about exercise as it applies to individuals with cardiovascular or heart disease, those who have COPD (chronic obstructive pulmonary disease), patients with emphysema, and athletes or prospective athletes with asthma. People with each of these disorders have special challenges related to exercise and need to make adjustments to their exercise program in order to be able to be active. This isn't to say that these are individuals who cannot exercise; on the contrary, through exercise they may enhance their physical fitness levels and levels of functioning in daily activities.

Chapter eleven topic was obesity and exercise. The obese person should be able to exercise despite being overweight and may lose weight as a result. In fact, few people can lose weight and sustain their weight loss without some form of physical activity. The types of physical activity that can safely be undertaken in the obese patient and how much exercise should be done to lose weight were also discussed.

Chapter twelve discussed type 1 and type 2 diabetes and the role that exercise has in the prevention and management of these conditions. Exercise is known to improve insulin sensitivity and to decrease the risk of developing type 2 diabetes. Exercise is strongly beneficial in helping patients who already have type 2 diabetes. Individuals with type 1 diabetes will also benefit from exercise but need to take special precautions with regard to diet and insulin use while being physically active.

Chapter thirteen focused on sports, exercise, and the various injuries the athlete can get while playing sports. It started with the topic of overtraining in athletes as well as the relatively common “overtraining syndrome” in which the exercising athlete simply exercises too much and burns out. Muscle injuries in the athlete and other orthopedic injuries, including stress fractures of the lower extremities, were covered. There are many different orthopedic injuries an athlete can get, which were also discussed.

Course Questions and Answers

1. What layer surrounds the muscle fiber and provides nutrients to each muscle fiber?

    a. Fascicle
    b. Perimysium
    c. Epimysium
    d. Endomysium

    > Answer: d. The endomysium is a connective tissue layer that surrounds each muscle fiber in order to supply blood and nutrients to the muscle cell.

2. What connective layer surrounds each skeletal muscle in order to define the muscle and separate it from other tissues, allowing muscle fibers to act in coordination?

    a. Fascicle
    b. Perimysium
    c. Epimysium
    d. Endomysium

    > Answer: b. The perimysium is the outer layer of muscles that separate the muscle from other tissues, allowing muscle fibers to act in coordination so the entire muscle can act as a unit.

3. What is the structural unit of contraction of a muscle fiber called?

    a. Sarcomere
    b. Sarcolemma
    c. Fascicle
    d. Sarcoplasmic reticulum

    > Answer: a. The individual structural unit of contraction of a muscle fiber is called the sarcomere. It consists of the actin and myosin

filaments along with the supportive proteins that individually contract in the muscle fiber.

4. What is the thin filament protein in the muscle fiber?

   a. Troponin
   b. Tropomyosin
   c. Myosin
   d. Actin

   Answer: d. The thin filaments are called actin filaments, which slide against thick filaments in order to contract the muscle. The thick filaments are the myosin filaments and both troponin and tropomyosin are supporting muscle proteins.

5. What is the first source of ATP energy in the exercising muscle?

   a. Aerobic metabolism
   b. Glycolysis
   c. Creatine phosphate metabolism
   d. Lactic acid metabolism

   Answer: c. The initial source of ATP energy in the exercising muscle happens with the metabolism of creatine phosphate to make ATP from ADP and the phosphate from the creatine phosphate.

6. What source of ATP energy in the actively contracting muscle cell takes place in the mitochondria of the cell?

   a. Aerobic metabolism
   b. Glycolysis
   c. Creatine phosphate metabolism
   d. Lactic acid metabolism

   Answer: a. Aerobic metabolism takes place within the mitochondria, taking the pyruvate from glycolysis and further metabolizing the glucose into CO_2, H_2O, and ATP energy.

7. Which of the following creates the most ATP in the exercising muscle?

   a. Aerobic metabolism
   b. Glycolysis
   c. Creatine phosphate metabolism
   d. Lactic acid metabolism

      Answer: a. Aerobic metabolism in the mitochondria creates the most ATP energy—up to 36 molecules of ATP per molecule of glucose used. This process requires oxygen.

8. About how long will creatine phosphate provide energy to the muscle cell upon initiation of muscle contraction?

   a. 1 second
   b. 15 seconds
   c. 1 minute
   d. 15 minutes

      Answer: b. Creatine phosphate only provides energy for 15 seconds of activity after the initiation of muscle activity in the exercising muscle.

9. What allows a muscle to shorten to a state that is the shortest the muscle cells can be?

   a. Extensibility
   b. Elasticity
   c. Contractility
   d. Relaxation

      Answer: c. It is the contractility of the muscle fiber that allows the muscle to contract to a state that is its shortest possible state. Elasticity allows the muscle to relax to its resting state and extensibility involves the stretching of the muscle to its longest state.

10. Which muscles relax in order to increase the blood flow to the exercising muscle while the athlete is exercising?

    a. Peripheral blood vessel smooth muscle
    b. Skeletal muscle
    c. Cardiac muscle
    d. Visceral smooth muscle

    Answer: a. The peripheral blood vessel smooth muscle will relax in order to increase blood flow to the exercising muscle in order to allow the athlete to exercise. Cardiac and skeletal muscle will increase their contractility in the exercise process.

11. Which type of muscle fibers fatigue the slowest because they have a sustained source of energy?

    a. Fast glycolytic fibers
    b. Fast oxidative fibers
    c. Slow oxidative fibers
    d. Slow glycolytic fibers

    Answer: c. Slow oxidative fibers make use of aerobic respiration. They will last longer than fast oxidative and fast glycolytic fibers and will fatigue the slowest.

12. Which type of muscle fibers will fatigue the fastest because they operate only with glycolysis, which does not last very long?

    a. Fast glycolytic fibers
    b. Fast oxidative fibers
    c. Slow oxidative fibers
    d. Slow glycolytic fibers

    Answer: a. Fast glycolytic fibers or FG fibers are those that react quickly but also fatigue the fastest because they do not make use of aerobic respiration in order to function.

13. Which muscle fibers are considered the thickest and most powerful of all muscle fibers?

 a. Fast glycolytic fibers
 b. Fast oxidative fibers
 c. Slow oxidative fibers
 d. Slow glycolytic fibers

 Answer: a. The fast-glycolytic fibers are white and are the thickest so that they can react with the most power and against the greatest forces the body can come up against.

14. When the Cori cycle takes place in the human body, what is the end product in the liver of this type of process?

 a. Pyruvate
 b. CO_2 and water
 c. Lactate
 d. Glucose

 Answer: d. The Cori cycle takes glucose from the muscle cell, makes lactic acid as part of metabolism, and recreates glucose in the process of gluconeogenesis in the liver, making glucose the end product of this cycle.

15. Which activity in human exercise most relies on the white muscle fibers?

 a. Swimming
 b. Sprinting
 c. Marathon running
 d. Walking

 Answer: b. White muscle fibers are the fast muscle fibers that participate in activities requiring a burst of energy, such as sprinting. The other activities primarily make use of red muscle fibers.

16. What is the main energy source for slow or red muscle fibers?

    a. Amino acids
    b. Glycogen
    c. Glucose
    d. Fatty acids

    Answer: d. Fatty acids and their beta-oxidation are the greatest source of energy for slow or red muscle fibers that require fatty acids for their long-term functioning.

17. When it comes to muscles, what is a motor unit?

    a. The muscle fiber and its motor nerve it innervates
    b. The cluster of muscle fibers innervated by a single motor nerve
    c. The entirety of the muscle itself
    d. The neuromuscular junction and the muscle fiber

    Answer: b. The cluster of muscle fibers innervated by a single motor nerve is called a motor unit. A motor unit can involve a small number of muscle fibers in a small motor unit or a large number of muscle fibers in a large motor unit.

18. In a muscle contraction or twitch, what is the first phase of the twitch?

    a. Latent phase
    b. Recovery phase
    c. Relaxation phase
    d. Contraction phase

    Answer: a. In the latent phase, there is propagation of the action potential and release of calcium ions but there will be no actual contraction occurring yet.

19. A lack of muscle tension or a decreased level of muscle tension in a muscle is referred to as what?

a. Hypertonia
b. Treppe
c. Hypotonia
d. Atrophy

> Answer: c. Hypotonia is a lack of muscle tension or decreased levels of muscle tension in a given muscle. It can be secondary to CNS damage or other muscle disease.

20. What is age-related muscle mass decrease referred to as?

a. Atrophy
b. Sarcopenia
c. Hypotonia
d. Hypertrophy

> Answer: b. The natural age-related muscle mass decrease is called sarcopenia and happens even when an older person is physically active.

21. What is not a phenomenon of endurance training of muscles?

a. Muscle thickening
b. Increased capillary supply to muscles
c. Increased myoglobin in the muscle fiber
d. Increased mitochondria in the muscle fiber

> Answer: a. Each of these will occur in the muscles that are engaging in endurance training except that there will not be muscle thickening as is seen in resistance training.

22. Which chamber of the heart receives blood from the pulmonary circuit or from the lungs?

a. Right atrium
b. Right ventricle
c. Left atrium
d. Left ventricle

Answer: c. The left atrium receives blood from the pulmonary circuit, which is the blood that is oxygenated and is coming from the lungs.

23. Which chamber of the heart pumps oxygenated blood to the systemic circulation?

a. Right atrium
b. Right ventricle
c. Left atrium
d. Left ventricle

Answer: d. The left ventricle receives oxygenated blood from the left atrium and sends the blood to the systemic circulation by pumping this blood out of the heart.

24. Which chamber of the heart has blood leaving it through the mitral valve?

a. Right atrium
b. Right ventricle
c. Left atrium
d. Left ventricle

Answer: c. The left atrium sends oxygenated blood through the mitral valve and into the left ventricle.

25. Which chamber of the heart pumps deoxygenated blood out of the pulmonic valve?

   a. Right atrium
   b. Right ventricle
   c. Left atrium
   d. Left ventricle

      Answer: b. The right ventricle handles deoxygenated blood and pumps it through the pulmonic valve to the pulmonary circuit.

26. Which valve separates the right atrium and the right ventricle in the heart?

   a. Tricuspid valve
   b. Pulmonic valve
   c. Mitral valve
   d. Aortic valve

      Answer: a. The tricuspid valve separates the right atrium and the right ventricle in the heart, making it the most similar to the mitral valve, which separates the left atrium and the left ventricle.

27. What is the main function of the papillary muscles in the heart?

   a. They contract in order to help push blood out of the ventricles.
   b. They contract in order to prevent backflow through the atrioventricular valves.
   c. They contract in order to open the atrioventricular valves.
   d. They are vestigial and have no function in adult humans.

      Answer: b. These papillary muscles are located in the ventricles and will contract in order to prevent the backflow of blood from the ventricles to the atria through the atrioventricular valves.

28. When evaluating the heart sounds of a healthy individual, what cardiac event is associated with the S1 or "first" heart sound?

   a. Regurgitation of blood through the aortic valve
   b. Closure of the atrioventricular valves
   c. Blood flow through the mitral valve and tricuspid valve
   d. Closure of the aortic valve and pulmonic valve

      Answer: b. The heart sound called the S1 or first heart sound is associated with the closure of the atrioventricular valves, both the mitral and tricuspid valves together. Closure of the aortic valve and pulmonic valve is associated with the S2 or second heart sound. Both blood flow through the mitral valve and tricuspid valve as well as regurgitation through the aortic valve are heard as heart murmurs rather than the traditional S1 and S2 heart sounds.

29. What is the outermost layer of the pericardium around the heart?

   a. Serous pericardium
   b. Epicardium
   c. Parietal pericardium
   d. Fibrous pericardium

      Answer: d. The outermost layer of the pericardium is the tough fibrous pericardium, which is also the densest of these layers of the pericardial sac.

30. What role does the anatomy of the coronary arteries play in the cause of heart attacks?

   a. There are too many branches to these arteries that get built up with plaque.
   b. These are narrower arteries than are seen in other arteries of the body.
   c. There is not a great deal of overlap between these arteries so blockages are more dangerous.

d. The arteries have many anastomoses, which increase the risk of heart attacks.

Answer: c. These arteries do not have a great deal of overlap between them so that blockages are more likely to cause a heart attack. These overlaps would be caused by anastomoses or connections between the arteries; however, there are not many anastomoses in the coronary circulation.

31. What is the major difference between cardiac muscle cells and skeletal muscle cells?

a. There aren't any Z-lines with the cardiac muscle fibers.
b. There is no actin and myosin in cardiac muscle cells.
c. The skeletal muscle fibers tend to be shorter than cardiac muscle fibers.
d. There is automaticity of cardiac muscle fibers that isn't present in skeletal muscle fibers.

Answer: d. The major difference between these two types of cells is that cardiac muscle fibers have inherent autorhythmicity that isn't seen in skeletal muscle fibers. They have similar sarcomeres as is seen in skeletal muscle but the fibers are not as regularly placed as is seen in skeletal muscle fibers.

32. What structure is seen in cardiac muscle cells that isn't seen in skeletal muscle cells?

a. Intercalating discs
b. Z-discs
c. T-tubules
d. Sarcomeres

Answer: a. The intercalating discs in cardiac muscle will join two cells together, providing a mechanism of communication between the cells so they can contract in unison. Both cardiac and skeletal muscle cells have sarcomeres, T-tubules, and Z-discs, although the T-tubules are less plentiful in cardiac muscle.

33. Which aspect of the heart has the fastest rate of automaticity?

a. Atrioventricular node
b. Sinoatrial node
c. Bundle of His
d. Purkinje cells

Answer: b. The sinoatrial node or the SA node has the fastest rate of automaticity, making it the main pacemaker of the healthy heart.

34. In order to cause depolarization of the cardiac muscle cells, what ion leaks steadily into the cell to cause spontaneous depolarization?

a. Potassium
b. Chloride
c. Sodium
d. Calcium

Answer: c. There is a steady leak of sodium into the cell that causes spontaneous depolarization of the cell and automaticity of the cardiac muscle cell. Calcium will aid in this process, while potassium repolarizes the cell.

35. What accounts for a decreased potential for tetany in the cardiac contractile muscle cells versus skeletal muscle?

a. An increase in refractory period length
b. A more negative potential in the resting cell
c. A lack of slow sodium channels
d. An inability to allow calcium through the sarcolemma

Answer: a. There is an increase in the length of the refractory period in cardiac contractile muscle cells versus skeletal muscle, accounting for the decreased chance of tetany, which would not be compatible with life.

36. What is the inherent autorhythmicity rate of the sinoatrial node of the heart?

    a. 100-120 beats per minute
    b. 80-100 beats per minute
    c. 60-80 beats per minute
    d. 40-60 beats per minute

        Answer: b. The inherent autorhythmicity rate for the SA node is about 80-100 beats per minute in the healthy person. There are parts of the heart that have slower autorhythmicity rates should the SA node fail to function properly.

37. In the ECG, what wave represents the depolarization of the atria?

    a. P wave
    b. U wave
    c. QRS complex
    d. T wave

38. Answer: a. Each aspect of the depolarization and repolarization of the heart with the P wave representing the depolarization of the atria. The QRS wave represents the depolarization of the ventricles.

    a. What is the approximate cardiac output at rest in a healthy person?
    b. 2 liters per minute
    c. 5 liters per minute
    d. 10 liters per minute
    e. 20 liters per minute

        Answer: b. The resting cardiac output is four to eight liters per minute, with an average of about 5.25 liters per minute. This can increase to as much as eight times this level in a highly-trained athlete.

39. If no parasympathetic influence occurs to the heart, what will the SA node rate be at rest with sympathetic tone only?

a. 40 beats per minute
b. 80 beats per minute
c. 100 beats per minute
d. 220 beats per minute

Answer: c. With sympathetic tone applied to the resting heart only, the heart rate will be 100 beats per minute. This means that there is usually some parasympathetic tone applied along with sympathetic tone to get the resting autonomic tone of the heart.

40. What is the maximal heart rate as designated by the maximum rate that can be applied to the atrioventricular node?

a. 150 beats per minute
b. 220 beats per minute
c. 250 beats per minute
d. 300 beats per minute

Answer: b. While the SA node has the ability to send faster impulses than 220 beats per minute, the maximal rate of the heart in a healthy person is determined by the AV node, which can send a maximum signal at 220 beats per minute.

41. The fact that exercise increases the heart rate in the athlete is a result of what factor mainly?

a. Proprioceptor reflex
b. Bainbridge reflex
c. Chemoreceptor reflex
d. Limbic reflexes

Answer: a. The proprioceptor reflex will increase the heart rate in exercise by increasing the stimuli coming in from moving muscles, joints, and tendons during the exercise process.

42. During exercise, what aspect of the cardiovascular system remains roughly the same?

a. Cardiac output
b. Heart rate
c. Stroke volume
d. Blood pressure

> Answer: d. The cardiac output, stroke volume, and heart rate will all increase; however, there are factors regarding the exercising body that cause the blood pressure to stay the same.

43. What is the lining of the lungs and chest cavity called?

a. Hilum
b. Mediastinum
c. Pleura
d. Plexus

> Answer: c. The pleura is the lining of the lungs and chest cavity. It is formed by the visceral pleura (which lines the lungs themselves) and the parietal pleura (which lines the chest cavity surrounding the lungs).

44. Under normal resting circumstances, what is the major factor in the act of inspiration?

a. The contraction of the diaphragm
b. The contraction of neck muscles
c. The relaxation of the diaphragm
d. The relaxation of intercostal muscles

> Answer: a. The contraction of the diaphragm is the major event that occurs in order to cause the influx of the air into the lungs with inspiration. The neck muscles do not become significantly involved until there is deep inspiration or forced expiration. The intercostals do contract in inspiration but this is a lesser force than is seen with the diaphragm.

45. When doing equations for pressure in the lungs and the breathing process, what is the set point for the pressure of air first entering the body?

a. One atmosphere
b. 760 millimeters mercury
c. Zero millimeters of mercury
d. 760 torr

Answer: c. The arbitrary set point of the pressure in the surrounding air first entering the body is zero with other pressures being negative or positive, depending on the circumstances. The actual pressure as identified by science is one atmosphere, 760 millimeters of mercury, and 760 torr but these are not used in the biological understanding of pressures in relation to the lungs.

46. Which lung pressure is considered the pressure between the lungs and the chest wall?

a. Intrapleural pressure
b. Atmospheric pressure
c. Intra-alveolar pressure
d. Transpulmonary pressure

Answer: a. The intrapleural pressure is the pressure between the lungs themselves and the chest wall. It is considered to be about -4 millimeters of mercury—negative enough to keep the lungs inflated and attached to the chest wall.

47. Which type of breathing requires the use of muscle contraction to help in the expiratory process?

a. Eupnea
b. Quiet breathing
c. Costal breathing
d. Hyperpnea

48. Answer: d. Hyperpnea or forced breathing requires the contraction of musculature for both the inspiratory and expiratory process with muscles of the abdomen and chest wall contracting and allowing the chest wall to force air out.

    a. What is the name for the amount of air that is left in the lungs after a forced expiration?
    b. Residual volume
    c. Forced exhalation volume
    d. Expiratory reserve volume
    e. Tidal volume

    Answer: a. The residual volume is the amount of air left in the lungs after a forced exhalation. This is the amount that is necessary to keep the lungs from completely collapsing.

49. What is the approximate amount of the vital capacity for the lungs?

    a. 1000 milliliters
    b. 4000 milliliters
    c. 6000 milliliters
    d. 8000 milliliters

    Answer: b. The vital capacity for the lungs is the amount that can be taken in by the lungs minus the residual volume. This is about 4000 milliliters in the average person.

50. The medulla oblongata is located in the brain and responds to certain things in order to affect the respiratory rate. Which of the following is not considered something this part of the brain responds to in this regard?

    a. Carbon dioxide levels
    b. Oxygen levels
    c. Potassium levels
    d. pH level

Answer: c. The medulla oblongata will respond to any of these levels in the bloodstream; however, it does not respond to the potassium level changes in the body.

51. What part of the brain sets the normal baseline respiratory rate?

   a. Pontine pneumotaxic center
   b. Dorsal respiratory group
   c. Pontine apneustic center
   d. Ventral respiratory group

   Answer: b. Each of these is a part of the brain that plays a role in the rate and depth of breathing; however, it is the dorsal respiratory group that sets the normal baseline respiratory rate.

52. What will change in response to a low pH in the body when it comes to respirations?

   a. Respirations will stop if the pH is below normal levels
   b. Respiration depth but not the rate will increase
   c. Respiration rate and depth will decrease
   d. Respiration rate and depth will increase

   Answer: d. Low pH means acidity, which can be from acids building up in the bloodstream or carbon dioxide buildup. The brain is stimulated by this, resulting in an increase in the rate and depth of respirations.

53. What is the major factor involved in stimulating respirations by chemoreceptors in the aortic arch and carotid arteries?

   a. Low oxygen levels
   b. High pH levels
   c. High carbon dioxide levels
   d. Low carbon dioxide levels

   Answer: c. High carbon dioxide levels will pull the pH down with chemoreceptors in the aortic arch and carotid arteries responsible for increasing respirations.

54. Which gaseous substance makes up the greatest concentration in the air?

  a. Nitrogen
  b. Carbon dioxide
  c. Oxygen
  d. Water vapor

    Answer: a. Nitrogen makes up the vast majority of the gaseous content in air.

55. Which gas is least soluble in blood?

  a. Carbon dioxide
  b. Oxygen
  c. Nitrogen
  d. Water vapor

    Answer: c. Nitrogen is not very soluble in water so that it does not diffuse easily across the respiratory membrane despite its high concentration.

56. What gas is most soluble in blood?

  a. Nitrogen
  b. Carbon dioxide
  c. Oxygen
  d. Oxygen and carbon dioxide have similar solubilities

    Answer: b. Carbon dioxide is 20 times more soluble in blood versus that of oxygen and infinitely more soluble than nitrogen. This allows it to be transported across the respiratory membrane (as it is highly soluble in alveoli too) even though it crosses with a lesser pressure differential compared to oxygen.

57. Which law or effect indicates that carbon dioxide is more able to be bound to hemoglobin under low oxygen tensions?

a. Boyle's law
b. Henry's law
c. Dalton's law
d. Haldane effect

Answer: d. The Haldane effect involves an increased affinity of hemoglobin for carbon dioxide under lower oxygen tensions.

58. Which law or effect of gases affects a gases ability to go from a gaseous phase to a liquid phase?

a. Boyle's law
b. Henry's law
c. Dalton's law
d. Haldane effect

Answer: b. Henry's law governs the effect of gases and gas transport from a liquid to a gaseous phase based on the partial pressures and concentration of gases in solution.

59. Which effect accounts for the greater dissociation of oxygen from hemoglobin at low pH levels?

a. Haldane effect
b. Bohr effect
c. Dalton effect
d. Henry effect

Answer: b. The Bohr effect refers to the greater dissociation of oxygen from hemoglobin at low pH levels, which means that those cells and tissues with higher carbon dioxide levels have lower pH levels and greater availability of oxygen for metabolic use.

60. What will not change as part of long-term exercise as it relates to the lungs and exercise?

a. The capillaries around the alveoli will increase.
b. The respiratory muscles will strengthen.
c. Gas exchange will be more efficient.
d. Resting respiratory rate will increase.

Answer: d. Each of these things will be altered with long-term exercise except for the resting respiratory rate, which will not increase with long-term exercise.

61. What is not an advantage of anaerobic exercise?

a. It can build muscle mass.
b. It can enhance muscle strength.
c. It can improve lactic acid removal.
d. It will burn more calories than aerobic exercise.

Answer: d. The major advantages of anaerobic exercise are that it can build muscle mass and strength, improve lactic acid removal, and enhance the VO2 max (maximal uptake of oxygen); it does not, however, burn more calories than aerobic exercise.

62. At what target heart rate or above is the exercise considered anaerobic?

a. 50 percent of maximum
b. 80 percent of maximum
c. 90 percent of maximum
d. 100 percent or maximum heart rate

Answer: b. Any time the heart rate in an exercise program reaches 80 percent of maximum or more, it is considered an anaerobic exercise.

63. What is the most accurate explanation of the difference between resistance and strength training?

   a. There is no actual difference between the two.
   b. Strength training implies building muscle mass, while resistance training doesn't necessarily do this.
   c. Strength training is an anaerobic exercise, while resistance training is mostly aerobic.
   d. Strength training involves doing just one or two heavy lifts, while resistance training involves doing several reps at a time.

      Answer: b. Strength training can be described as a type of resistance training that involves the building of muscle mass and strength, while resistance training can involve toning without an increase in muscle mass.

64. What is considered a natural anabolic steroid?

   a. Creatine
   b. Insulin-like growth factor
   c. Growth hormone
   d. Testosterone

      Answer: d. While insulin-like growth factor, growth hormone, and testosterone are used in the anabolic process of muscle building during resistance training, only testosterone is considered an anabolic steroid because it has the ability to have anabolic effects on muscle.

65. About how many training exercises with resistance training are recommended per week?

   a. one to two
   b. two to three
   c. three to four
   d. six to seven

Answer: b. Only about two to three sessions of resistance training are recommended per week. This will strengthen the muscles and will allow the necessary time for healing of the muscles between sessions of training. Too many of these types of exercises without recovery will only damage the muscles.

66. In training the muscles during resistance training, what is the number of reps that should be done in order to reach muscle fatigue at the end of the repetition series?

a. 2 to 3
b. 6 to 8
c. 10 to 12
d. 15 to 20

Answer: c. The muscles should feel fatigued at 10 to 12 repetitions in order to create the process that tones and builds muscles. This is the number of reps that should be done for each muscle group in the resistance training exercise program.

67. Which muscles will hypertrophy to the greatest degree with resistance training?

a. Fast glycolytic
b. Slow glycolytic
c. Fast oxidative
d. Slow oxidative

Answer: a. The fast-glycolytic fibers are the anaerobic fibers, which tend to hypertrophy to a greater degree with resistance training because these are the fibers that get activated in this type of short-term exercise.

68. With resistance training and adaptation of muscle fibers, what is not an adaptation in the muscles that occurs?

a. Increased volume of sarcoplasm
b. Increased connective tissue
c. Increased muscle fiber number
d. Increased numbers of myofibrils

Answer: c. Each of these will increase with resistance training except for the number of muscle fibers. The number of muscle fibers is dictated at the time of birth and does not change, even with exercise and weight training. The myofibrils (actin and myosin bundles), sarcoplasm, and connective tissue volume will increase, resulting in hypertrophy.

69. What is not something that is seen as an adaptation to resistance training?

a. Heart volume increase
b. Heart rate reduction
c. Blood pressure decrease
d. Improved glucose tolerance

Answer: c. Each of these will be positive health effects in resistance training; however, there has not been found to be a significant reduction in baseline blood pressure with this type of exercise.

70. What is described as the workout volume when it comes to resistance training?

a. The number of reps multiplied by the weight applied
b. The total weight applied per repetition
c. The total weight applied for a given set of 10 repetitions
d. The total amount of time spent during a resistance training workout

Answer: a. The workout volume is the number of repetitions multiplied by the weight applied. This should be gradually increased as part of the exercise plan.

71. What is the major neurological adaptation seen when a person resistance-trains over time?

   a. Increased firing rate to the slow-twitch muscles
   b. Decreased co-contraction of antagonist muscles
   c. Increased motor neuron production to agonist muscles
   d. Increased size of the motor end plate

      Answer: b. There will be decreased firing on the antagonist muscles so that there is less co-contraction of these muscles and a greater force that can be applied by the agonist muscles.

72. Which of these hormones is not considered an anabolic hormone secreted as part of resistance training?

   a. Testosterone
   b. Insulin
   c. Cortisol
   d. Growth hormone

      Answer: c. Each of these is an anabolic hormone secreted in response to resistance training; however, cortisol is considered a catabolic hormone that is also secreted with resistance training.

73. Which hormone's resting concentration will be elevated with prolonged resistance training?

   a. Norepinephrine
   b. Growth hormone
   c. Estrogen
   d. Testosterone

      Answer: d. The testosterone level will be chronically elevated whenever the athlete engages in ongoing resistance training.

74. What is the maximum heart rate in a healthy individual?

   a. 220 beats per minute
   b. 220 beats per minute minus the athlete's age
   c. 150 beats per minute plus the athlete's age
   d. 200 beats per minute minus the athlete's body mass index

      Answer: b. The maximum heart rate during exercise is 220 beats per minute minus the athlete's age. The target heart rate for aerobic and anaerobic heart rate is based on this maximum.

75. What body area most benefits from aerobic exercise?

   a. Cardiovascular system
   b. Musculoskeletal system
   c. Endocrine system
   d. Nervous system

      Answer: a. While there are benefits to each of these systems in aerobic exercise, the cardiovascular and respiratory systems most benefit from aerobic exercise.

76. What is the primary source of ATP energy when aerobic exercise is undertaken?

   a. Glucose
   b. Glycogen
   c. Protein
   d. Fatty acids

      Answer: d. Fatty acids and their hydrolysis become the main source of energy used to make ATP in aerobic exercise. When anaerobic exercise kicks in or starts the exercise process, glucose is used instead.

77. How is the heart rate reserve for aerobic exercise calculated?

   a. Max heart rate minus the age
   b. Max heart rate for age minus the resting heart rate
   c. Resting heart rate times 70 percent
   d. 220 beats per minute minus the resting heart rate

      Answer: b. The maximum heart rate for age minus the resting heart rate is what can be defined as the heart rate reserve. This is the rate that is multiplied by 40 to 85 percent and added to the resting heart rate to get the target heart rate for aerobic exercise.

78. What is the approximate number of calories per hour that a 150-pound person will expend while stationary cycling?

   a. 100
   b. 250
   c. 500
   d. 750

      Answer: c. Stationary cycling expends about 500 calories per hour. This is slightly less than the number of calories that can be expended during outdoor cycling. Both are good forms of exercise because they can be done by many different people and for an extended period of time.

79. An individual has a family history of sudden cardiac death at a young age. What would an appropriate evaluation include?

   a. Exercise stress test
   b. Echocardiogram
   c. Doppler ultrasound
   d. Pulmonary function test

      Answer: a. This person is at risk for sudden cardiac death, which can be partially predicted by performing an exercise stress test that will show evidence of coronary artery narrowing and ischemia of the heart muscle with exercise.

80. Which type of cancer will be partially prevented by long-term aerobic exercise?

a. Stomach cancer
b. Lung cancer
c. Leukemia
d. Colon cancer

Answer: d. There appears to be a benefit to aerobic exercise when comes to preventing colon cancer and breast cancer among women. The exact reason why this is the case is not completely clear.

81. Which exercise is least effective as an aerobic exercise for weight loss?

a. Swimming
b. Walking
c. Running
d. Cycling

Answer: a. While swimming is an effective form of aerobic exercise, it does not lead to as much weight loss as other forms of exercise. However, there is less impact with swimming making it better for individuals with joint issues.

82. What is the approximate VO2 max in men and women who are sedentary in milliliters per kilogram per minute?

a. 10
b. 20
c. 35
d. 55

Answer: c. The average VO2 max in the sedentary male or female is 30 to 35 milliliters per kilogram per minute.

83. What is the lactate threshold measured in units?

a. Milligrams per kilogram per minute
b. Milligram percent
c. pH units
d. Percent of VO2 max

Answer: d. The lactate threshold is a measure of when the lactate level spikes during intense exercise because the lactate being produced is greater than that which can be eliminated. It is measured as a percent of the VO2 max and increases with increased training.

84. What is not increased in the heart with ongoing aerobic exercise?

a. Resting heart rate
b. Cardiac output
c. Ventricular muscle mass
d. Stroke volume

Answer: a. The stroke volume will increase as well as the muscle mass. This increase in stroke volume will mean an increase in cardiac output without an increase in resting heart rate, which will actually decrease at rest.

85. What is not an advantage of cross-training for an elite athlete?

a. It will combat boredom while exercising.
b. It will help prevent injuries.
c. It will increase the VO2 max.
d. It can allow for exercise through injury.

Answer: c. The cross-training program will prevent injuries, allow exercise through injury, and will combat boredom, making this helpful for all elite athletes.

86. How can cross-training improve weight loss in athletes?

a. Athletes will burn more calories during their cross-training episodes.
b. Athletes can exercise for longer periods of time when switching up activities.
c. Exercising different muscles will burn additional calories.
d. Cross-training has little effect on weight loss.

Answer: b. Athletes will be able to exercise for longer periods of time because different activities and different muscles are used while exercising. Longer periods of time exercising enhance weight loss in general.

87. What is the major reason why muscles have less stamina in colder environments?

a. There is more lactic acid building up during cold weather exercise.
b. The cardiac output is reduced in cold weather.
c. There are fewer slow twitch muscles in cold weather environments.
d. The muscles generate too much heat in colder environments.

Answer: a. There is more lactic acid built up because of an increase in fast twitch fiber recruitment in cold weather. This leads to an acidic environment, which causes increased muscle fatigue and decreased muscle stamina in this type of weather.

88. What is the preferred source of fuel for muscles in cold weather?

a. Triglycerides
b. Glycogen
c. Cholesterol
d. Amino acids

Answer: b. Both glycogen and glucose will be utilized preferentially by muscles in a cold environment, leading to a loss of these energy stores more quickly and a breakdown in stamina.

89. What leads to increased risk of dehydration in cold weather?

a. There is actually a decreased risk of dehydration in cold weather.
b. There is more sweating in cold weather.
c. There is a diminished thirst drive in cold weather.
d. Water isn't absorbed as well in cold weather.

Answer: c. There is a decreased thirst drive in cold weather because the normal mechanisms of dry mouth and cues to thirst are impaired in this type of environment.

90. At what body temperature does the first signs of hypothermia appear in the athlete?

a. 37 degrees Celsius
b. 35 degrees Celsius
c. 32 degrees Celsius
d. 30 degrees Celsius

Answer: b. The normal core body temperature is 37 degrees. When this drops just two degrees Celsius, the beginning of hypothermia first occurs.

91. What is the greatest advantage to exercising in cold weather versus warm weather?

a. There is less body water lost in cold weather.
b. There are more calories expended in cold weather.
c. There is increased muscle mass gained in cold weather.
d. There is increased stamina in cold weather.

Answer: b. Because of metabolic demand, there are more calories expended in cold weather so that, in the end, there is increased fat burning and a greater chance of losing weight.

92. A person with what disorder needs least to be cautious in working out in cold weather?

a. A person with heart disease
b. A person with asthma
c. A person with arthritis
d. A person with Raynaud's disease

Answer: c. Each of these individuals will need to be particularly cautious about exercising in cold weather but a person with arthritis does not need special precautions as long as they warm up, which is recommended in every person working out in the cold.

93. When working out in cold weather, what should the inner layer be in terms of dressing for the workout outside?

a. Something waterproof
b. A cotton layer
c. Fleece or wool
d. A synthetic fabric layer

Answer: d. The inner layer should be something synthetic that wicks moisture away. This should be covered in a fleece or wool layer and then a waterproof but breathable layer. Cotton does not insulate when it gets wet so it should be avoided.

94. What is the main cause of decreased cardiac output in the hydrated athlete?

a. Increased blood pooling in the extremities
b. Decreased contractility of heart muscle
c. Increased resistance to blood flow
d. Increased blood pressure

Answer: a. The blood will pool in the extremities in hot weather, which causes a decrease in preload and a subsequent decrease in cardiac output, even in the hydrated athlete.

95. What is considered a first-line treatment for the athlete with heat cramps?

a. Intravenous fluids
b. Gentle exercise
c. Ice packs
d. Oral electrolyte solution

Answer: d. The treatment for heat cramps, which is a combination of low fluid volume and low sodium in the system is to give oral electrolyte solution. Ice packs and IV fluids are reserved for heat exhaustion or heat stroke but are unnecessary in heat cramps. Gentle exercise will not generally help and may make heat cramps worse.

96. What is the main complication of heat stroke?

a. Dehydration
b. Syncope
c. Brain damage
d. Electrolyte disturbances

Answer: c. Heat stroke is very serious and results in end organ damage, including permanent brain damage that can lead to death in the athlete who becomes so dehydrated and who has such a high body temperature that death can ensue.

97. How often should salt tablets be consumed during exercise?

a. Salt tablets are not recommended during exercise.
b. Salt tablets should be consumed only after exercise.
c. Salt tablets should be consumed if heat cramps start.
d. Salt tablets should be used during exercise only.

Answer: a. Salt tablets are not recommended at all because they contribute to dehydration and are not helpful in preventing heat-related injuries.

98. About how much fluid should be consumed in hot weather during exercise?

a. 500 milliliters before and after exercise.
b. One liter per hour if already hydrated at the beginning of exercise.
c. Two liters per hour during and for one hour after exercise.
d. Five hundred milliliters per hour

Answer: b. About one liter per hour should be consumed as long as the athlete is already hydrated at the time of starting the exercise.

99. What is the major benefit seen in hot yoga versus regular yoga?

a. Improvement in body mass index
b. Increased flexibility
c. Increased muscle strength
d. Improved mood

Answer: a. Because hot yoga raises the basal metabolic rate, it can result in a loss of body weight and a reduction in the body mass index that isn't seen as much in regular yoga. All forms of yoga will increase flexibility and muscle strength, and all yoga will improve overall mood.

100. Which factor makes it the most difficult to be oxygenated near the summit of Mount Everest?

a. Low oxygen concentration
b. Cold temperatures
c. Low oxygen pressures
d. Low humidity levels

Answer: c. The percent of oxygen in the air is the same all over the earth but the partial pressure (and total air pressure) will be decreased at this elevation. The cold and dry air contribute to breathing discomfort but do not affect oxygenation as much as the partial pressure of oxygen reduction at the summit.

101. What respiratory effect of altitude does not happen in the athlete at higher altitudes?

a. VO2 max decreases
b. Oxygen diffusion rate in the lungs decreases
c. Respiratory rate increases
d. Percent saturation of hemoglobin increases

Answer: d. The rate of diffusion of oxygen at the alveolar level and at the tissue level will decrease so that the VO2 max decreases, even as the respiratory rate increases. The percent saturation of oxygen, which is normally about 98 percent, will be decreased at higher elevations.

102. What happens to the plasma volume and cardiac output in the first few hours after arriving at high altitudes in the training athlete?

a. The plasma volume will decrease and the cardiac output will decrease.
b. The plasma volume will decrease and the cardiac output will increase.
c. The plasma volume will increase and the cardiac output will decrease.
d. The plasma volume will increase and the cardiac output will increase.

Answer: b. The plasma volume will decrease by as much as 25 percent within hours of arrival and this effectively concentrates the blood. The heart rate increases so that the cardiac output at rest will increase because of overshooting of the heart rate.

103. About how long does it take for the athlete to become fully acclimatized to high altitudes for competition?

a. 48 hours
b. one week
c. two weeks
d. four weeks

Answer: d. It actually takes four to six weeks to fully acclimatize to high altitudes but the major effects can begin to be seen by two weeks at higher altitudes.

104. What happens to muscles in the athlete training at high altitude?

a. The muscle diameter decreases and weight is lost.
b. The muscle diameter decreases but weight is gained.
c. The muscle diameter increases and weight is gained.
d. The muscle diameter increases and weight is lost.

Answer: a. The muscle diameter will decrease at high altitude because the body will catabolize the muscle for energy. This is accompanied by a reduction in appetite, which causes overall weight loss.

105. When starting an exercise program, how many minutes of aerobic exercise per week should be the ultimate goal?

a. 60 minutes
b. 90 minutes
c. 150 minutes
d. 280 minutes

Answer: c. The recommended amount of exercise is 150 minute per week. This is usually divided into 30-minute increments, done five days a week up to the maximum recommended.

106. What is measured in a body composition analysis using skinfold calipers?

a. Amount of body fat
b. Percent muscle mass
c. Dry body weight
d. All of these are measured

Answer: a. Skinfold calipers will measure the amount of body fat but will not measure the muscle mass, percent muscle mass, or dry body weight. Because of this and because of user-specificity, it does not easily measure body composition clearly.

107. Which body composition measurement tool can be used at home and measures many body composition values?

a. Skinfold calipers
b. Hydrostatic testing
c. DEXA scan
d. Bioelectric impedance testing

Answer: d. Bioelectric impedance testing usually involves a scale and will measure many body composition values. These are for sale at a reasonable price and can be used in the home without the necessity of a technician.

108. What is the upper limit for percent body fat in women?

a. 5 percent
b. 15 percent
c. 25 percent
d. 35 percent

Answer: c. A normal body fat percentage for women is 18 to 25 percent. Numbers that are higher than this put an individual woman at a higher risk for obesity-related problems.

109. What are the units for body mass index?

a. Kilograms per meter squared
b. Kilograms per meter cubed
c. Kilograms
d. It has no units

Answer: a. According to the calculations, the body mass index is measured in kilograms per meter squared. It is the mass in kilograms divided by the height squared in meters.

110. What is the lower limit of healthy when it comes to body mass index?

a. 12
b. 18.5
c. 26
d. 34

Answer: b. The lower limit of healthy when it comes to body mass index or BMI is 18.5. Anything lower than this is considered underweight and is associated with the health problems seen in the underweight person.

111. What is not a major adverse effect of taking anabolic steroids?

a. Fatigue
b. Low sperm count
c. Gynecomastia
d. Scrotal pain

Answer: a. Each of these is a side effect of taking anabolic steroids; however, instead of fatigue there is agitation, anger, and irritability when taking this type of ergogenic aid.

112. What is not a side effect of using caffeine in sporting events?

a. Increased muscle contractility
b. Diuresis
c. Increased body temperature
d. Increased concentration

Answer: c. Each of these is a side effect of taking caffeine in athletics; however, it will not increase body temperature.

113. Which ergogenic aid is completely legal to take, according to many sporting authorities?

a. DHEA
b. Creatine
c. Caffeine

d. Testosterone

Answer: b. Creatine is the only product of these that not only enhances athletic performance in some circumstances but it is completely legal to take at any dose for athletic competition.

114. Which ergogenic aid is considered illegal?

a. Glycerol
b. GHB
c. HMB
d. Yohimbine

Answer: b. Each of these has been used as an ergogenic aid for exercise training; however, GHB, which increases human growth hormone is illegal to take.

115. Which ergogenic aid seems to have some known benefit?

a. Selenium
b. Sodium bicarbonate
c. Magnesium
d. Tribulus terrestris

Answer: b. Of those listed, only sodium bicarbonate, which buffers lactic acid, has been found to be helpful in some athletic circumstances.

116. What best predicts an individual's ability to tolerate physical activity when determining the proper exercise prescription?

a. Age
b. Heart rate after five minutes of exercise
c. Exercise stress test
d. VO2 max

Answer: d. The VO2 max is the best predictor of aerobic capacity and ability to tolerate physical activity. An exercise stress test can tell if there is any evidence of heart disease with exercise. Heart rate evaluations and age are not necessarily good predictors of exercise potential.

117. When is the best time to recommend that the obese person exercise?

a. After a light meal in the afternoon
b. In the evening after dinner
c. After breakfast
d. In the morning before eating

Answer: d. The obese person can maximize fat burning or lipolysis by exercising first thing in the morning before eating breakfast.

118. What type of exercise should be least recommended in persons with hypertension?

a. Swimming
b. Isometrics
c. Strength training
d. Yoga

Answer: b. People with hypertension will have an increased risk of high blood pressure exacerbations with isometric exercise. They can still do strength training and the other activities.

119. What form of exercise is least recommended for the person with osteoporosis?

a. Swimming
b. Brisk walking
c. Stationary cycling
d. Weight lifting

Answer: a. The best exercise for the person with osteoporosis is some type of weight-bearing exercise, stationary cycling, and weight lifting or some resistance training. Swimming, while healthy, does not stress the bones and joints enough to help osteoporosis.

120. Which is a polysaccharide (chain of monosaccharides) that is most easily digested by the human body?

a. Sucrose
b. Chitin
c. Starch
d. Cellulose

Answer: c. Starch comes from potatoes and other starchy vegetables. It is a complex carbohydrate consisting of chains of glucose molecules. Both chitin and cellulose are indigestible polysaccharides, while sucrose is a disaccharide.

121. Which disaccharide is found in table sugar?

a. Maltose
b. Chitin
c. Lactose
d. Sucrose

Answer: d. Sucrose is a mixture of glucose and fructose—a disaccharide that can be found in table sugar. It is often consumed by athletes as a way of getting a sudden increase in available sugars.

122. For what reason are whole grain carbohydrates recommended for consumption by many people, including athletes?

a. They are a quick source of energy.
b. They contain a lot of fiber, which slows the absorption of sugar.
c. They are more easily absorbed when compared to other carbohydrates.
d. The carbohydrates more easily get turned into glycogen than simple carbohydrates.

Answer: b. Whole grain carbohydrates are recommended for consumption because they contain a lot of fiber that slows the absorption of sugar from the GI tract. Much of the fiber consists of cellulose or other fiber that does not get absorbed at all.

123. What is the storage form of sugar in the human body?

a. Amylum
b. Cellulose
c. Glycogen
d. Sucrose

Answer: c. Glycogen is found in muscles and in the liver as the main storage form of glucose sugar in the human body. The muscle glycogen is readily available for use by athletes during aerobic and even anaerobic training.

124. Which organ or part of the body contains the most glycogen as a storage form of glucose in the human body?

a. Liver
b. Muscles
c. Brain
d. Bloodstream

Answer: b. Glycogen can only be found in the muscles and liver, with muscle glycogen making up the majority of the glycogen in the human body. This is because the muscles need a ready source of glucose from glycogen in order to be functional during exercise.

125. What is the preferred energy source for brain cells?

a. Amino acids
b. Fatty acids
c. Triglycerides
d. Glucose

Answer: d. The brain uses only glucose as its energy source under most circumstances so some carbs are necessary in the diet in order to fuel the brain. Low blood sugars translate to insufficient energy to brain cells.

126. At what glycemic index is the carbohydrate considered to be high?

a. Above 20
b. Above 40
c. Above 70
d. Above 100

Answer: c. Any glycemic index above 70 is considered high. The upper limit for glycemic index is 100, so that numbers between 70 and 100 are rapidly-acting on the blood sugar after a meal or any intake of carbohydrates.

127. Which food will have the lowest glycemic index?

a. Apple-flavored candy
b. Apple juice
c. Applesauce
d. Apple

Answer: d. Foods that are not cooked or processed and as close to their natural form will have the lowest glycemic index, while cooking or processing raises the glycemic index.

128. For what sport is carb-loading most beneficial?

a. Body-building
b. Marathon running
c. Sprinting
d. Resistance training

Answer: b. Carb-loading is important for endurance athletics so it is most beneficial for athletes in endurance sports like marathon running. It is less helpful for anaerobic activities and activities that require a short burst of energy.

129. When eating protein, what is considered the healthiest source of protein compared to others?

a. Legumes
b. Fish
c. Chicken
d. Steak

Answer: a. Legumes are high in protein and do not contain any unhealthy fat or salt. Plants in general do not contain cholesterol, which is an unhealthy form of fat in the diet. Fish would be the second-best protein with steak being the least-helpful of all protein sources—even for the athlete in training.

130. When is protein intake most important to the average athlete?

a. One week before exercise
b. One day before exercise
c. During exercise
d. One to two hours after exercise

Answer: d. Protein should be consumed within a couple of hours after exercise in order to repair muscle protein right after an athletic event or excessive exercise.

131. Which of the following is not considered a macronutrient?

a. Fat
b. Protein
c. Vitamins
d. Carbohydrates

Answer: c. Carbohydrates, protein, and fats are the three main macronutrients in the diet. They are called macronutrients because they are taken and recommended in large amounts. Only small amounts of vitamins are recommended in the diet; these are considered micronutrients.

132. How many calories are there in one gram of fat?

a. 4
b. 9
c. 13
d. 17

Answer: b. Fat has the highest number of calories per gram, containing nine calories per gram of fat consumed.

133. Which type of fat should the athlete avoid eating altogether?

a. Saturated fat
b. Monounsaturated fat
c. Trans fat
d. Polyunsaturated fat

Answer: c. Trans fat comes from the processing of food and is not found in nature. For this reason, these types of fats should not be taken in by the athlete in any quantity.

134. What provides the best fuel storage for endurance athletes?

a. Carbohydrates
b. Amino acids
c. Protein
d. Triglycerides

Answer: d. The stored fuel for endurance athletes is triglycerides, which are oxidized and used for fuel for any activity lasting longer than about 90 minutes so marathon runners and endurance cyclists use these for fuel.

135. How many calories can be found in a gram of protein?

a. 2
b. 4
c. 9
d. 12

Answer: b. Protein and carbohydrates contain the same number of calories per gram of food taken in at four calories per gram. These values are both less than half of the number of calories per gram of fat taken in.

136. What is the body fat percentage in females after puberty on average?

a. 10 percent
b. 15 percent
c. 25 percent
d. 35 percent

Answer: c. The body fat percentage in girls will increase due to the effects of estrogen to about 25 percent of the total body weight. This is not seen in boys, who maintain a 12 to 14 percent body fat after puberty.

137. Which disorder affects female athletes and is associated with knee pain, particularly with running activities?

a. ACL tear
b. Sever’s disease
c. Osgood-Schlatter syndrome
d. Patellofemoral syndrome

Answer: d. Patellofemoral syndrome mainly affects female athletes and is due to the lack of ability of the patella or kneecap to ride smoothly in the patellar groove. It can be treated with strengthening exercises.

138. What disorder primarily affects boys and is seen as upper tibial pain at the tibial tubercle, made worse with physical activity?

a. ACL tear
b. Sever’s disease
c. Osgood-Schlatter syndrome
d. Patellofemoral syndrome

Answer: c. Osgood-Schlatter syndrome is a condition where the tendons that attach to the tibial tubercle become inflamed at their point of attachment, resulting in pain in front of the upper tibia, particularly in athletes.

139. What is not true of the aerobic and anaerobic capacities of young athletes?

a. They have smaller stroke volumes when compared to adults.
b. They have greater VO2 max compared to adults.
c. They have less glycogen storage capacity compared to adults.
d. They have greater anaerobic capacity compared to adults.

Answer: d. Children have less anaerobic capacity compared to males but greater aerobic capacity with higher VO2 max levels even with a smaller stroke volume when compared to adults. They have less glycogen built up in the muscles.

140. What is least contributing to the epidemic of childhood obesity?

a. Genetic factors
b. Increased screen time
c. Decreased physical education in schools
d. Fast food and sodas

Answer: a. While there are genetic factors that can play a role in obesity in children, this is a smaller role than any of the other factors that add to overeating and lack of exercise in the youth of Western societies.

141. What is the minimum number of calories an active female needs in order to maintain reproductive health and have an adequate energy balance?

a. 1000
b. 1400
c. 1800
d. 2200

Answer: c. The minimum number of calories an active female athlete requires to maintain energy balance and reproductive health is about

1800 calories. This is enough to maintain weight, even in a moderately active adult female.

142. Which micronutrient is most likely to be deficient in the female athlete not getting in enough energy intake?

a. Iron
b. Calcium
c. Folate
d. Vitamin B12

Answer: a. Iron is most likely to be deficient in the female athlete who does not get in enough in the way of energy intake, although deficiencies in the other things can also be the case.

143. What vitamin deficiency is seen more commonly in athletes who exercise indoors?

a. Vitamin C
b. Vitamin B12
c. Vitamin D
d. Folate

Answer: c. Athletes who primarily exercise indoors have a risk of developing a vitamin D deficiency because they do not tend to get enough vitamin D from the sunshine.

144. What is not necessarily a part of the female athlete triad?

a. Menstrual dysfunction
b. Eating disorder
c. Energy intake deficiency
d. Decreases in bone mineral density

Answer: b. Each of these is a part of the female athlete triad; however, it is not necessarily the case that every person with the triad has an eating disorder.

145. An athlete who consistently binge eats and purges after eating in order to maintain her weight is said to likely have what disorder?

a. Anorexia nervosa
b. Binge eating disorder
c. Bulimia nervosa
d. Eating disorder, not otherwise specified

Answer: c. The cycle of binge eating and purging along with the possibility of over-exercising is called bulimia nervosa. This is different from anorexia nervosa because these women often have a normal or near-normal body weight.

146. A lack of what hormone in the female athlete is likely to account for the decreased bone mineral density sometimes seen in these athletes?

a. Progesterone
b. Estrogen
c. Thyroxine
d. Triiodothyronine

Answer: b. There is a disordered hypothalamic-pituitary-ovarian axis in these athletes, who often have low estrogen levels and subsequently have an inhibition in the ability to make bone. This results in a low bone mineral density.

147. Which type of exercise is most beneficial for older adults who might be at risk for falling?

a. Tai chi
b. Weight lifting
c. Swimming
d. Stretching

Answer: a. Tai chi is a form of balance exercise so that it is most helpful in preventing falls due to balance disturbances in the older adult.

148. Which older adult least likely needs exercise stress testing before starting a training program?

a. Those with osteoarthritis
b. Those with autonomic neuropathy
c. Those with peripheral arterial disease
d. Those with coronary artery disease

Answer: a. Those with autonomic neuropathy have a difficult time recognizing over activity because they do not feel chest pain normally. Those with peripheral vascular disease have a high risk for heart disease and those with coronary artery disease are at risk for problems with physical activity. Each of these should have an exercise stress test. The average older adult with osteoarthritis does not necessarily need an exercise stress test before exercise training programs.

149. What activity will most enhance the bone mass density of the older adult?

a. Aerobic training
b. Resistance training
c. Balance training
d. Flexibility training

Answer: b. Resistance training is the main activity known to enhance the bone mass density in the older adult who has osteopenia or who is otherwise at risk for osteoporosis.

150. What is not true of the effects of exercise on cholesterol levels in heart disease patients?

a. It will lower HDL cholesterol levels
b. It will lower LDL cholesterol levels
c. It will lower triglyceride levels
d. It will lower total cholesterol numbers

Answer: a. HDL cholesterol or the “good” cholesterol actually increases with exercise. In fact, exercise is one of the few things that will increase this cholesterol number. Exercise will also lower the total cholesterol, LDL cholesterol, and triglyceride levels.

151. In patients with heart disease, what cardiovascular parameter will increase with vigorous physical activity done on a regular basis?

a. Heart rate
b. Lipid levels
c. Ejection fraction
d. Blood pressure

Answer: c. Vigorous activity in heart disease patients will increase the ejection fraction of the heart, mainly by increasing contractility. The other parameters will be decreased with regular physical activity.

152. What is the range of rate of perceived exertion or RPE in the Borg scale?

a. 6 to 20
b. 0 to 10
c. 1 to 20
d. 1 to 50

Answer: a. The range for the RPE on the Borg scale is from 6 to 20, with six being no exertion and anything above 14 being high intensity exertion.

153. What is considered the least likely evidence of cardiac ischemia during exercise?

a. ST segment depression during exercise on the ECG
b. Ventricular tachycardia seen on the ECG during exercise
c. Tachycardia with exercise
d. Chest discomfort during activity

Answer: c. Each of these represents a sign of possible ischemia with exercise in the patient with heart disease; however, tachycardia is to be expected and bradycardia (slow heart rate) during exercise is considered far greater evidence for ischemia during exercise.

154. What will exercising with oxygen do for the individual who has COPD?

a. It will improve the function of the lungs.
b. It will aid in reversing lung disease during exercise.
c. It will improve the shortness of breath with exercise.
d. It does not generally help with exercise.

Answer: c. The patient with COPD can have improvement in their shortness of breath with exercise but it will not reverse lung disease or improve overall lung function.

155. The person with COPD should have what emphasis placed on aerobic fitness, flexibility, and strength training.

a. The emphasis should be on aerobic fitness but with strength training and flexibility also done.
b. Because of lung capacity problems, the focus should be on flexibility first, strength second, and aerobic fitness last.
c. Strength training is not necessary in COPD but aerobic fitness should be performed regularly.
d. Because of aerobic limitations, only strength training and flexibility should be undertaken.

Answer: a. The emphasis should be on aerobic fitness but strength training and flexibility should also be undertaken. Only aerobic fitness will improve lung function but the other exercises are important.

156. What is true about individuals with asthma and exercise?

a. They can exercise maximally with the proper treatment.
b. They should be able to exercise in low-level physical activity.
c. Many should not exercise at all because of the risk.
d. They should avoid certain activities that make asthma worse.

Answer: a. Asthmatics should be able to exercise maximally and many do when they receive proper treatment.

157. Which exercise activity is least likely to be impacted by exercise-induced asthma?

a. Swimming
b. Snow skiing
c. Sprinting
d. Cycling

Answer: c. Exercise-induced asthma is mainly seen in endurance and winter sports but it tends not to be seen in anaerobic, short-term activities like sprinting.

158. In recommending a sport for an asthmatic child, what would be considered the best choice among these?

a. Swimming
b. Long-distance running
c. Football
d. Snow shoeing

Answer: c. Any type of team sports is preferred because it doesn't have the consistently high minute volumes necessary in the other sports. Swimming seems to increase the risk for bronchospasm as does any outdoor winter sport (because of the cold, dry air).

159. What is the first line drug used for the athlete who has exercise-induced asthma?

a. Inhaled corticosteroids
b. Short-acting beta agonists
c. Ipratropium
d. Long-acting beta agonists

Answer: a. Because inflammation is the underlying cause of the problem, the anti-inflammatory inhaled corticosteroid drug is considered the first-line treatment.

160. Which drug is banned by most anti-doping agencies because they give the asthmatic athlete an unfair advantage?

a. Inhaled corticosteroids
b. Inhaled albuterol
c. Both of these
d. Neither of these

Answer: d. Neither of these drugs are banned by anti-doping agencies because they do not provide a performance advantage to the athlete who does not need to use them. They do not affect overall performance unless the athlete actually needs it because they have asthma.

161. Which sport is known to carry the highest risk of exercise-induced asthma?

a. Horseback riding
b. Running
c. Swimming
d. Hockey

Answer: c. Swimmers have more than a 90-fold increased risk in developing exercise-induced asthma, particularly in those athletes who swim competitively.

162. How many calories need to be reduced in order to lose one pound of body weight?

a. 1000
b. 1800
c. 2300
d. 3500

Answer: d. It takes 3500 calories (Food calories and not the typical calories seen in physics) of negative energy balance in order to lose one pound of body weight. The typical diet is about 2000 to 2500 calories per day so it takes several days of low intake and exercise to lose a pound of weight.

163. What is the definition of the basal metabolic rate?

a. The number of calories burned during sleep
b. The number of calories burned daily without physical activity
c. The number of calories burned daily
d. The number of calories eaten daily minus the number of calories burned daily

Answer: b. The basal metabolic rate or BMR is the number of calories burned per day without physical activity. It is the number of calories used for the basic metabolic processes, such as heart beating and breathing.

164. What risk factor for heart disease is most concerning with regard to the exercising individual?

a. Obesity
b. Hypertension
c. Family history of heart disease
d. Hyperlipidemia

Answer: b. Hypertension is considered to be of most concern with regard to exercise because hypertension can be made worse with exercise and should be more carefully evaluated in the higher-risk individual.

165. What is the main purpose of doing an exercise stress test in the obese individual?

a. To assess how much activity they should be able to do.
b. To see what type of activity they are best suited for.
c. To check their oxygenation levels during exercise.
d. To check for cardiac ischemia.

Answer: d. The main purpose of doing an exercise stress test is to check for cardiac ischemia during exercise. It can also be done to assess the VO2 max, which is an assessment of aerobic capacity.

166. What is the role of resistance training in weight loss?

a. It should be the mainstay of the exercise program.
b. It offers equivalent weight loss as compared to aerobic activity.
c. It can increase the fat-free mass so it should be performed.
d. It is not recommended as it doesn't offer weight loss benefits.

Answer: c. While resistance training alone does not offer weight loss benefits, it can increase the fat free mass and has other benefits that make it useful for the obese person.

167. What is considered to be the main cause of obesity in Western culture?

a. Consumption of high fat foods
b. Consumption of high carb foods
c. Lack of adequate exercise
d. A combination of high calorie intake and lack of exercise

Answer: d. It is widely believed that obesity is a combination of high energy food intake and lack of exercise and not due to any one thing.

168. What is true of the metabolic rate associated with exercise?

a. There is a significant increase in metabolic rate after exercise and a significant increase in metabolic rate with higher muscle amounts seen with exercise.
b. There is significant increase in metabolic rate after exercise but not a significant increase in metabolic rate with higher muscle amounts seen with exercise.
c. There is not a significant increase in metabolic rate after exercise but a significant increase in metabolic rate with higher muscle amounts seen with exercise.

d. There are increases in metabolic rate after exercise and increases in metabolic rate with higher muscle amounts seen with exercise but these are not significant.

Answer: d. While both of these statements are true with exercise, the amount of increase in metabolic rate seen with these things is not significant enough to impact weight loss.

169. What is recommended for the obese person to do after successfully losing weight?

a. Maintain 60 minutes of exercise daily in order to prevent weight gain.
b. Reduce physical activity to 30 minutes per day indefinitely to prevent weight gain.
c. Eat a healthy diet only with no increased activity recommended to prevent weight gain.
d. Resistance training is sufficient to prevent weight gain.

Answer: a. Because of the potential for weight regaining after weight loss, it is recommended that 60 minutes a day of moderate activity to be done indefinitely (or 35 minutes per day of vigorous activity daily).

170. Wearable devices can be used to measure fitness parameters. What is not available on these types of devices for those using them for exercise?

a. Glucose levels
b. Sleep quality
c. Steps taken
d. Oxygen levels

Answer: a. Each of these is something that can be done on certain fitness trackers except for glucose levels. Devices that can do these things are being engineered but are not yet available for the public.

171. When considering the effects of exercise on weight loss, which statement is true?

a. Exercise is more effective in losing weight than it is in maintaining weight.
b. Exercise is not effective in losing weight nor is it effective in maintaining weight once lost.
c. Exercise is just as effective in losing weight as it is in maintaining weight.
d. Exercise is most beneficial in preventing weight gain than it is in losing weight.

Answer: d. Exercise is most beneficial when it comes to preventing weight gain in the first place and less effective in actually losing weight once it was gained.

172. What is the main reason why exercise will decrease the glucose level in diabetics following the activity?

a. Insulin-independent synthesis of muscle glycogen
b. Increased insulin activity on the cells of the body
c. Insulin-dependent synthesis of muscle glycogen
d. Increased uptake of glucose to make liver glycogen

Answer: a. Increased insulin-independent synthesis of muscle glycogen after exercise will cause a reduction in serum glucose levels because this glycogen must be replaced.

173. How long will blood sugar decrease after exercise in the type 2 diabetic?

a. 2 hours
b. 8 hours
c. 24 hours
d. 48 hours

Answer: d. The blood glucose level will decrease after exercise in the type 2 diabetic for a total of about 48 hours, after which the effect disappears.

174. A diabetic who wishes to exercise has diabetic peripheral neuropathy. What exercise is preferred?

a. Running
b. Walking
c. Swimming
d. Cycling

Answer: c. A non-weightbearing exercise like swimming should be done in this case because the weight-bearing exercise will potentially be risky and can prevent the diabetic from recognizing when they have a foot injury and because they have difficulty feeling their feet.

175. How long into an exercise activity involving aerobic exercise should the diabetic expect that glycogen stores have been depleted?

a. 5 minutes
b. 20 minutes
c. 35 minutes
d. 60 minutes

Answer: b. The glycogen stores will be depleted at about 20 minutes into the aerobic activity. Past this point, fat begins to be oxidized and a carb may need to be taken in order to have an alternate glucose source.

176. What type of exercise program has the maximum effect on the glycemic control in the diabetic patient?

a. Aerobics and balance training
b. Resistance training by itself
c. Aerobic training plus flexibility training
d. Aerobics and resistance training

Answer: d. There appears to be an additive effect of doing aerobics and resistance training together that is better than doing either one separately in diabetics of all types.

177. What type of exercise in the diabetic will potentially increase the blood sugar during the exercise itself?

a. High-intensity exercise
b. Moderate-intensity exercise
c. Low-intensity exercise
d. Long-duration exercise

Answer: a. High-intensity exercise that increases catecholamines like adrenaline (epinephrine) will increase the blood sugar during the activity, although this will be temporary and will return to normal or low levels after the exercise is over with.

178. Which type of diabetic athlete requires insulin exclusively because they don't make their own?

a. Gestational diabetics
b. Prediabetics
c. Type 2 diabetics
d. Type 1 diabetics

Answer: d. Type 1 diabetics do not make their own insulin so they require some type of exogenous insulin at all times, even while exercising.

179. Which type of exercise has the greatest potential to cause severely low blood sugars and death during the following night in the type one diabetic?

a. Any aerobic activity occurring in the afternoon
b. An anaerobic activity done in the morning
c. A mixed aerobic and anaerobic activity at noon
d. An aerobic activity done when the blood sugar is greater than 250 milligrams per deciliter

Answer: a. Any aerobic activity done in the afternoon has the greatest risk of causing nocturnal hypoglycemia (low blood sugar at night) versus any other kind of activity.

180. For blood sugar levels before exercise between 90 and 124 milligrams per deciliter in a type 1 diabetic, what amount of sugar should be taken before exercising?

a. 5 grams
b. 10 grams
c. 20 grams
d. None is recommended

Answer: b. About 10 grams of glucose is recommended before exercise if the blood sugar level is between 90 and 124 milligrams per deciliter in a type 1 diabetic.

181. In type 1 diabetics, what type of food should be taken before and after exercise?

a. High glycemic index foods before exercise and high glycemic index foods after exercise
b. Low glycemic index foods before exercise and protein after exercise
c. High glycemic index foods before exercise and low glycemic index foods after exercise
d. Low glycemic index foods before exercise and both protein and high glycemic index foods after exercise

Answer: d. Performance is enhanced with low glycemic index foods taken a couple of hours before exercise, while both protein and high glycemic index foods are taken after exercise in order to replenish the stores of glycogen and to repair muscles.

182. What beverage is recommended in the diabetic exercising for short durations and who has a normal blood sugar?

a. Water
b. Milk
c. Gatorade or another sports drink
d. Caffeinated beverage

Answer: a. The recommendation for activities lasting less than 45 minutes in the diabetic with a normal blood sugar is water. Milk or Gatorade can be used after exercise. Caffeine may prevent low blood sugar during the activity but will increase the chance of nocturnal hypoglycemia after the event.

183. What is the biggest risk for the type 1 diabetic who exercises when it comes to blood sugar levels?

a. Exercise hyperglycemia
b. Exercise hypoglycemia
c. Post-exercise hyperglycemia
d. Post-exercise hypoglycemia

Answer: d. Post-exercise hypoglycemia is the biggest risk, with nocturnal hypoglycemia on the night after exercise being potentially deadly in the exercising diabetic, especially one who takes insulin.

184. When should the basal insulin dose be discontinued in the type 1 diabetic athlete?

a. When exercising longer than two hours
b. When doing intense anaerobic exercise
c. When doing an all-day tournament
d. It should never be discontinued

Answer: d. The basal insulin should never be discontinued in the type 1 diabetic. The only time the insulin should be reduced is after the exercise, when taking a bolus for the meal after the activity.

185. What is not considered a sympathetic overactivity issue seen in athletes suffering from overtraining syndrome?

a. Depression
b. Insomnia
c. Irritability
d. Tachycardia

Answer: a. Each of these is a sympathetic overactivity seen in athletes who suffer from overtraining syndrome; however, depression is a parasympathetic overactivity problem and not related to the sympathetic nervous system.

186. Which athlete training problem is most likely to be career-ending as it is not easy to recover from?

a. Functional over-exercising syndrome
b. Functional overreaching syndrome
c. Nonfunctional overreaching syndrome
d. Overtraining syndrome

Answer: d. Each of these is potentially recoverable; however, overtraining syndrome is the most difficult to overcome. It can take months to develop and months to recover from so it can potentially end the career of the overtraining athlete.

187. Which theory on overtraining syndrome uses inflammation as a tool for explaining the symptoms seen in this problem?

a. Glutamine hypothesis
b. Cytokine hypothesis
c. Hypothalamic hypothesis
d. Oxidative stress hypothesis

Answer: b. The cytokine hypothesis involves the finding of chronic microtrauma in the muscles, leading to cytokine production and an increase in inflammatory mediators, explaining many different symptoms seen in overtraining.

188. Which hypothesis on overtraining syndrome explains most of the phenomena seen in overtraining syndrome?

a. Cytokine hypothesis
b. Hypothalamic hypothesis
c. Oxidative stress hypothesis
d. Central fatigue hypothesis

Answer: a. The cytokine hypothesis explains many of the other hypotheses and findings seen in overtraining syndrome. For this reason, it is currently the main hypothesis but has not yet been proven.

189. How long after a period of rest without recovery of function qualifies as likely having overtraining syndrome?

a. One week
b. Three weeks
c. Two months
d. Six months

Answer: b. While many individuals can fail to recover their previous gains in performance after several months, a period of three weeks is necessary before the diagnosis can be made.

190. Which type of muscle injury is considered a type I injury?

a. Sprain
b. Strain
c. Partial tear
d. Complete tear

Answer: b. A muscle strain is a type I injury that involves less than five percent of the total muscle fibers in the entire muscle volume. It is the least serious of the muscle injuries.

191. What is the last stage of the injury-repair process?

a. Hematoma formation
b. Fibroblast infiltration
c. Connective tissue or scar formation
d. Myoblast differentiation

Answer: c. First, in a muscle injury, there is hematoma formation, followed by fibroblast infiltration and myoblast differentiation. Finally, the scar tissue or connective tissue forms and is made by the fibroblasts that infiltrate the muscle at the area of the injury.

192. What aspect of treating a muscle injury is least helpful in the first twenty-four hours after the injury?

a. Analgesics
b. Ice
c. Elevation
d. Compression

Answer: a. The PRICE protocol involves protection, rest, ice, compression, and elevation. These are important to healing and are more important than analgesics, which can actually impair the future function of the muscle.

193. Which athlete is least likely to be susceptible to shoulder tendonitis?

a. Swimmer
b. Golfer
c. Tennis player
d. Baseball player

Answer: b. Swimmers, tennis players, and baseball players have the greatest risk of this type of injury, which is mainly brought on by overuse and overhead movements of the shoulder. Golfers are can develop shoulder injuries but they don’t do a lot of overhead motion.

194. The friction-reducing membrane in the shoulder joint is referred to as what?

a. Rotator cuff
b. Shoulder ligament
c. Shoulder bursa
d. Shoulder joint capsule

Answer: c. A bursa is a membrane filled with lubricating fluid that reduces friction in the shoulder joint. It can become compressed or inflamed, leading to shoulder bursitis.

195. What is the major thing that leads to shoulder tendonitis?

a. Repetitive overhead motion of the shoulder
b. Fall on the outstretched arm
c. Shoulder dislocation
d. Repetitive sideways motion of the shoulder

Answer: a. Repetitive overhead motion of the shoulder most commonly leads to the development of shoulder tendonitis. This is why it happens most in swimmers, baseball players, and tennis players.

196. Which sport is least likely to lead to an ACL tear in the athlete?

a. Basketball
b. Football
c. Skiing
d. Golf

Answer: d. Each of these sports can result in an ACL tear because they involve planting of the foot and sudden twisting of the knee. This isn't seen in the golfer because there isn't the same mechanism of injury with this sport.

197. How long after an ACL injury can the younger athlete (less than 25 years) expect to have their ACL repair surgery?

a. Immediately
b. Two weeks
c. Six weeks
d. Eight weeks

Answer: c. It takes six weeks of healing and decreased swelling in order for the individual to expect to have an ACL surgery to actually repair the ligament.

198. What is the most common treatment done for the athlete who has a torn knee meniscus?

a. Meniscus trimming
b. Meniscus removal
c. Meniscus repair
d. Meniscus transplant

Answer: a. About 90 percent of surgeries to the meniscus is the trimming, although the other surgeries can also be done in less common situations.

199. The athlete is pushing off the foot in a game and experiences a sudden popping sensation in the back of the ankle and immediate weakness of the ankle. What is this most likely from?

a. Heel spur
b. Achilles tendinitis
c. Foot fracture
d. Achilles tendon rupture

Answer: d. This type of injury is seen in an Achilles tendon rupture and is identified by history and the mechanism of injury.

200. Where is lateral epicondylitis located when it comes to pain?

a. On the inner aspect of the elbow
b. On the back of the wrist
c. On the outer aspect of the elbow
d. On the inner aspect of the wrist

Answer: c. Lateral epicondylitis is also referred to as tennis elbow. It is pain from an overuse injury of the wrist that is located on the lateral aspect of the elbow.

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