TRAINER ACADEMY

FUNDAMENTALS OF PERSONAL TRAINING

1st EDITION

Certified Personal Trainer Textbook

Table of Contents

Chapter 1

The Skeletal System

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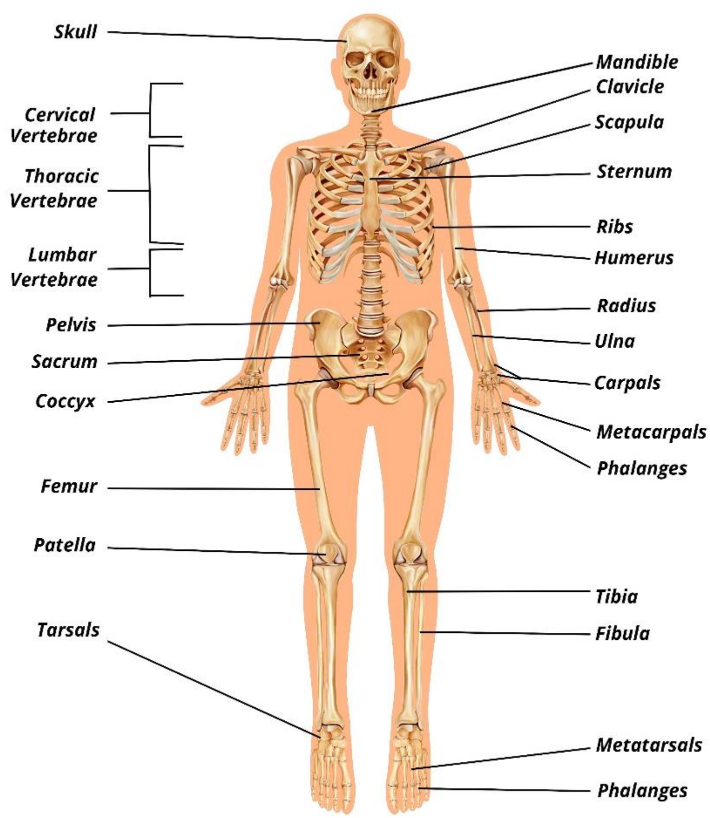
Introduction to the Skeletal System

Fitness professionals must have a basic understanding of skeletal system anatomy due to the key role it plays in all aspects of human life, including all movement and exercise. The bones, ligaments, tendons, and joints are all key structures in anatomy. Additionally, professionals must understand how disease and resistance training impacts these structures.

The **skeletal system** is an integral part of the human body. It supports body movement and protects vital organs. It serves as an attachment site for muscles and ligaments. In addition, the skeleton stores calcium, which is necessary for many body functions including cardiac function. Bones are also the primary production site for some types of blood cells. [1]



Human infants are born with approximately three hundred bones. As each person grows and develops, that number reduces due to bone fusion. Once a person reaches adulthood, their total number of bones drops down to two hundred and six.[1]

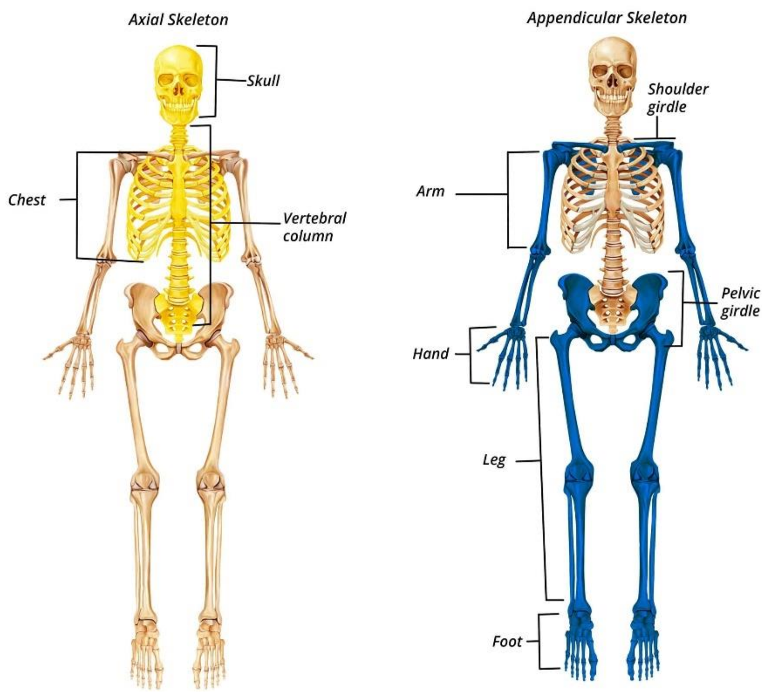
The human skeleton divides into two main parts – the axial and the appendicular skeleton.

The **axial skeleton** contains central bones such as the:

- Vertebrae
- Ribs
- Sternum
- Skull

It makes up eighty bones in all. The axial skeleton's primary function is to protect organs in the body's systems. These bones also contain attachment sites for muscles that assist with global support and balance.

The **appendicular skeleton** is made of one hundred twenty six bones that create the upper and lower limbs. These bones also include those of the pelvis and the shoulders. Their main function is to support movement in the extremities and serve as the attachment site for muscles.[1]



Bone Types

Bones are separated into categories based on their appearance. The four main types of bone are:

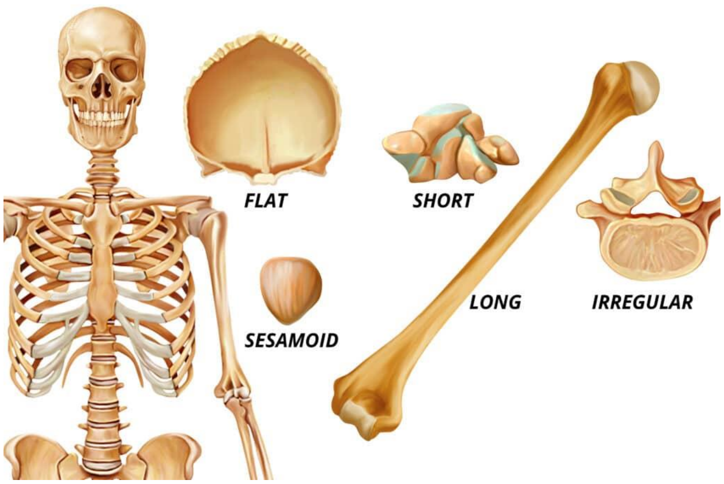
- Long bones
- Short bones
- Flat bones
- Irregular bones

The names used reflect the appearance of each bone category.[3]

Surrounding every bone is a tissue called periosteum, which covers most of the bone except for the locations where bones connect at a joint.

The periosteum is a membrane made of two layers – an outer layer made of connective tissue and an inner layer that contains bone stem cells. Blood vessels and nerves run through this membrane.[3]

Types of Bones



Long Bones

Long bones have a greater length than they do width or height. Most of the limb bones are long bones.

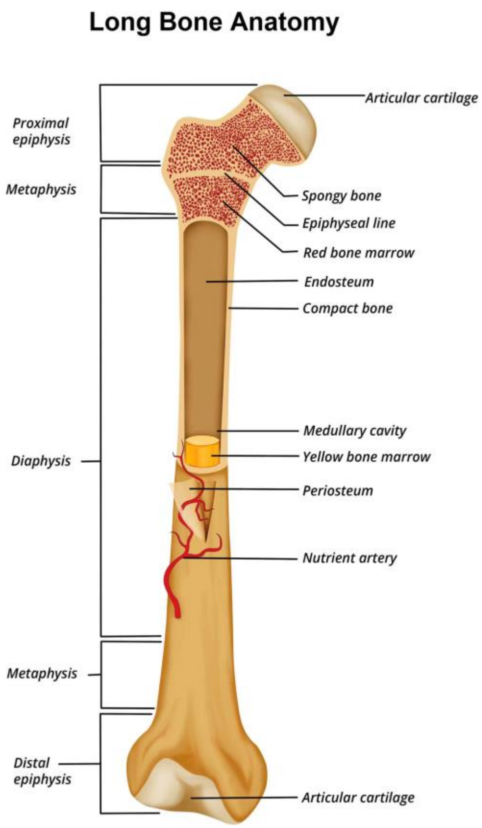
Each long bone has a diaphysis. The diaphysis is a shaft that makes up the middle length of the long bone.

On each side of the diaphysis sits the epiphysis. The epiphysis is the end of the long bone, so each long bone has two epiphyses.[3]

During childhood, long bones contribute to height increase and limb lengthening through epiphyseal plates. These growth plates are located in between the diaphysis and epiphysis and are made of cartilage that is replaced by bone as the plate grows. They allow for the lengthening of the long bones. Once a person reaches their maximal height and limb lengths in adulthood, the epiphyseal plates become epiphyseal lines that no longer actively contribute to the lengthening of the bones.[3]

Examples:

- Phalanges in the fingers
- Ulna and radius in the forearm
- Humerus in the arm[3]

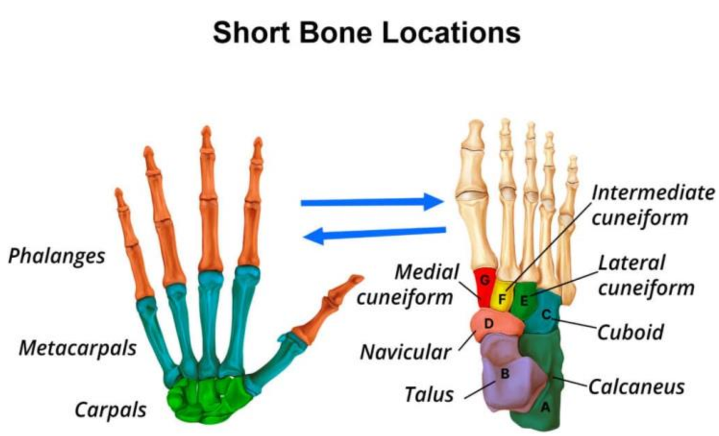


Short Bones

Short bones are cuboid in shape. Their measurements run similarly in length, height, and width.

Examples:

- Wrist bones
- Ankles



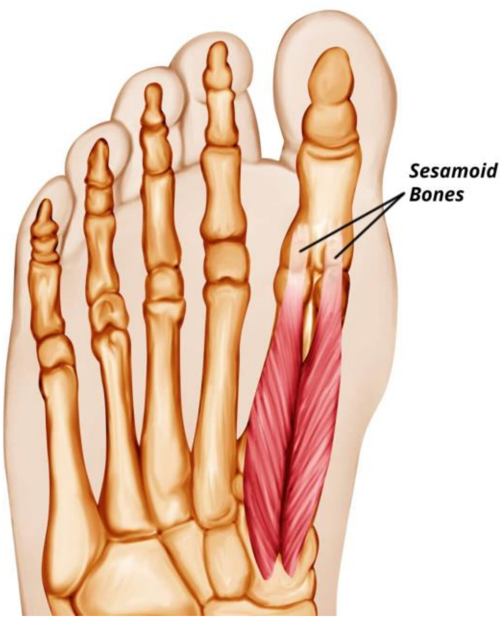
Sesamoid Bones

Sesamoid bones are short bones specifically found in tendons. Many of the sesamoid bones vary in size and location from person to person. They even range in number from person to person.[3]

Example:

- Patella in the kneecap

Sesamoid Bones in the Foot



Flat Bones

Flat bones are relatively flat as their name implies. Sometimes they have a curve to them, such as in the ribs.

Examples:

- Scapulae in the shoulders
- Cranial bones in the skull:
- Frontal
- Parietal
- Occipital

- Temporal[3]

Irregular Bones

Irregular bones are bones that do not fit into the category of long, short or flat bones. They have varying shapes depending on their specific function.

Examples:

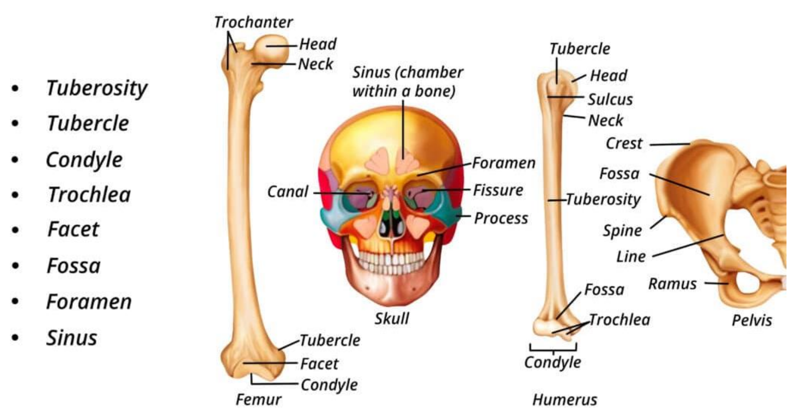
- Cervical vertebrae
- Thoracic vertebrae
- Lumbar vertebrae[3]

Bone Markings

In addition to categorizing individual bones, scientists also categorize the types of markings found on bones.

There are three main kinds of bone markings:

- Depressions
- Projections
- Surfaces



Depressions

Depressions are spaces on the bone through which nerves or blood vessels run through. These are further divided into categories such as:

- **Foramen** – holes or openings for nerves and blood vessels to pass through

- **Fissure** – open slits, grooves, or depressions typically housing nerves and blood vessels
- **Fossa** – broad and shallow depressions in the bone surface
- **Sulcus** – a furrow or fissure that in the case of bones typically traces the length of nerves or vessels–also called grooves when specifically discussing sulci on bones

Projections

Projections are the attachment sites of tendon and ligament to bone. Categories of projections include:

- Processes
- Condyle
- Epicondyle
- Process

Surfaces

Surfaces are the parts of the bone that attach to another bone to make a joint. These include facets and heads. Many depressions, projections, and surfaces found on bones have standard names anatomists use to recognize their location in the body.[3]

Bone Tissue Creation

Bone tissue is composed of many types of cells, including some that are specialized for the skeletal system. Two essential cell types found in the bone tissue are osteoblasts and osteoclasts. Osteoblasts are cells that help build bone. Osteoclasts help break down bone. These two cell types are important, because the body needs to build and break down bones throughout its lifetime.[1]

Wolff's Law

Wolff's Law is an important theory of the skeletal system related to bone creation.

This theory states that bone adaptations occur in response to the outside environment and the external forces the body experiences. According to Wolff's law, bone tissue changes over time by being built or broken down into different shapes, structures, and densities based on the environmental stresses placed on the bone.

For example, someone who becomes sedentary after trading their dog walking career for a new office job now primarily spends their day sitting at a desk. Since the bones now put much less stress on their bones, they begin to be broken down by osteoclasts. The body does not need as much bone to continue to protect all the organ systems and move. Therefore, over time, this individual's bones will become thinner and smaller.[2]

For another example, consider a professional soccer player who spends her day training for her sport. She strength trains at her gym, practices agility with her personal trainer, and does practice drills with her team. These environmental stressors trigger the skeletal system to react as her body is constantly supporting itself against many and varied outside forces.

Osteoblasts in the bone tissue are busy at work building stronger, denser bones. She needs these strong dense bones to protect her organs as she runs across the soccer field and to support powerful movements like kicking the ball into the goal.[2]

Connective Tissue in the Skeletal System

While bone tissue makes up a lot of the skeletal system, ligaments and tendons are also part of this body system.

Ligaments and tendons are made of connective tissue rather than bone tissue. Connective tissue differs from bone tissue in that it is more elastic and flexible. It primarily consists of type I collagen fibers surrounded by a mesh of loose connective tissue.[4] This allows for mobility and range of motion at each joint.[1]

Ligaments

Ligaments are connective tissues that connect one bone to another bone. They aid in holding the bones together while allowing a range of motion between the two bones.

Tendons

Tendons are connective tissues that attach muscle to bone, allowing the muscle to stretch without immediately tearing.[1]

Joints

Non-synovial joints are limited in mobility or completely immobile. They serve to connect bones of protection. The sutures of the skull bones (these bones protect the brain) and the fused vertebrae of the lower spine (these bones protect the spinal cord) are examples of non-synovial joints.[1]

Synovial Joints

In exercise science and personal fitness training, synovial joints are the main type of joint to focus on, as virtually all movement in the human body occurs around synovial joints.

Synovial joints are also the most common type of joints found in the body. They allow for large range of motion while protecting the bones that make up the joint. Between the bones at this type of joint, is a synovial capsule filled with fluid, conveniently named synovial fluid.

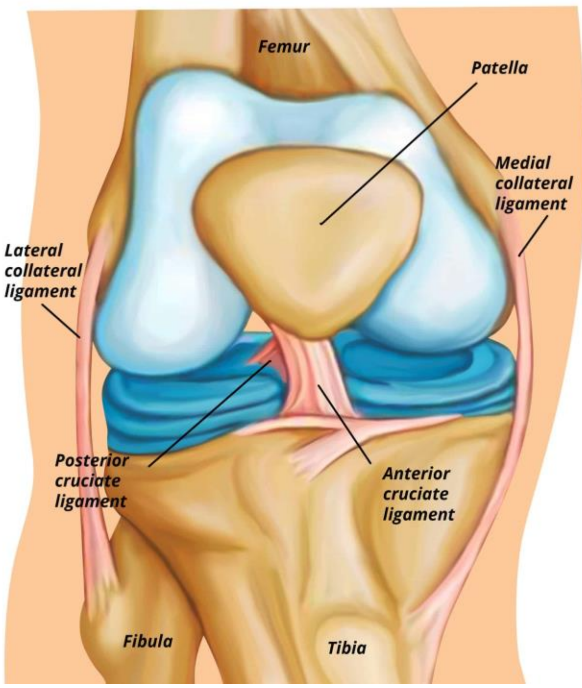
This capsule cushions the bones, preventing potential injury from two bones rubbing directly against each other. In addition to the synovial capsule, *ligaments* are also often found at synovial joints for added stability of the joint.[1]

Synovial joints have many different structures allowing for many different functions. Therefore, it makes sense to classify the synovial joints into subtypes based on their structures and functions.

The subtypes of synovial joints are:

- Gliding joints
- Ball-and-socket joints
- Pivot joints
- Hinge joints
- Saddle joints
- Condylar joints[1,2,3]

The Knee Joint



Gliding Joints

These are also known as plane joints. They move using a gliding movement as the name suggests – two bones are "gliding" against each other. They only allow for movement in one axis. This type of joint is found in the wrists and in ankles.[3]

Pivot Joints

Pivot joints create rotating movements. Like ball-and-socket joints, there are only a few joints in the body that display this kind of movement. The joints in the forearm composed of the ulna and radius are an example. When one places the palm of their hand on a surface in front of them and then flips the hand over so they can see their own palm, they are performing a movement using the pivot joints in their forearm.

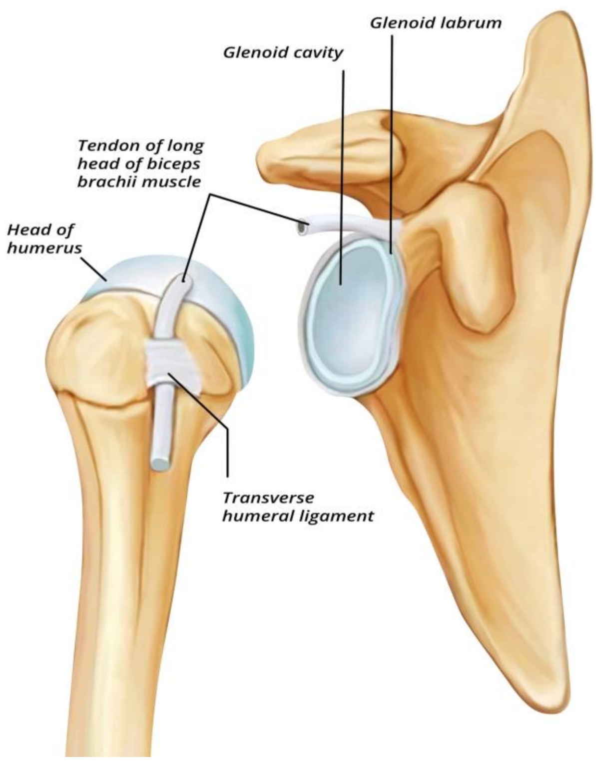
Hinge Joints

Hinge joints create a hinge movement – think of a hinge that connects a door to a doorway. They only allow for movement in one axis. Examples of these joints include the elbows, fingers, and toes.[3]

Ball-and-Socket Joints

Ball and socket joints have movements in many axes. Ball-and-socket joints have lots of mobility but contain much less stability. These joints are often the location of injury due to this lack of stability. Ball-and-socket joints include those in the hip joint and shoulder joints.[3]

The Glenohumeral Joint

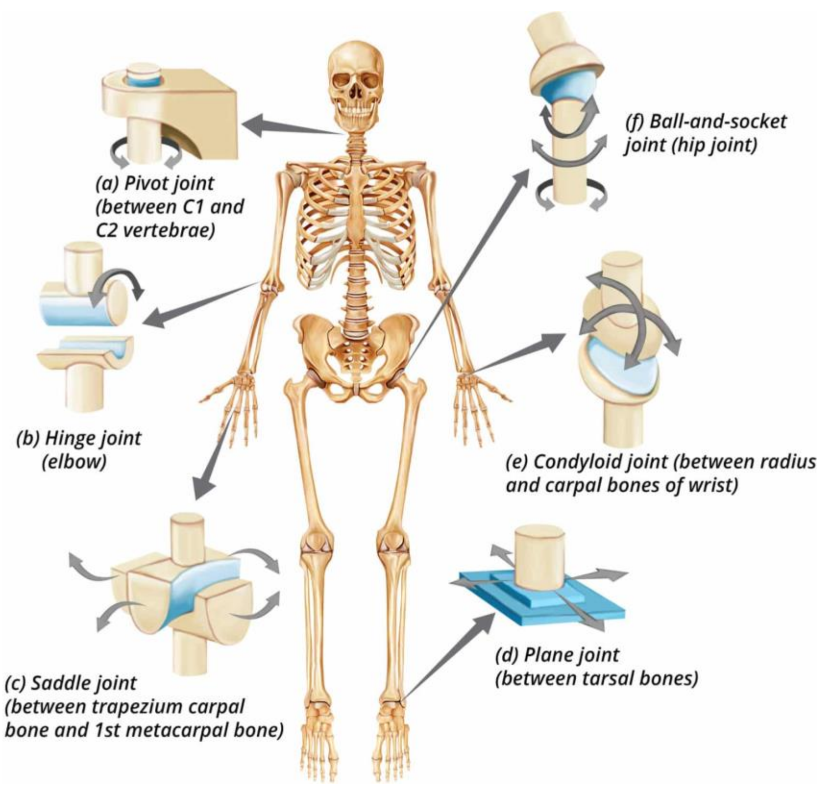


Saddle Joints

Saddle joints allow for movements in two axes. The joint is named because it looks like a saddle on a horse, with one bone surface surrounding the other. An example of a saddle joint is the saddle joint found in the thumb allowing for special opposable movements.[3]

Condyloid Joints

Condyloid joints also allow for movements in two axes. The easiest way to differentiate condylar joints from saddle joints is by their appearance. While saddle joints are shaped like saddles, condyloid joints look like two connected ovals. Each bone surface contributes an oval shape to this joint. Examples of condyloid joints include the joints in the knuckles, some joints in the wrist, and the knee joint.[3]



Bone and Joint Disease

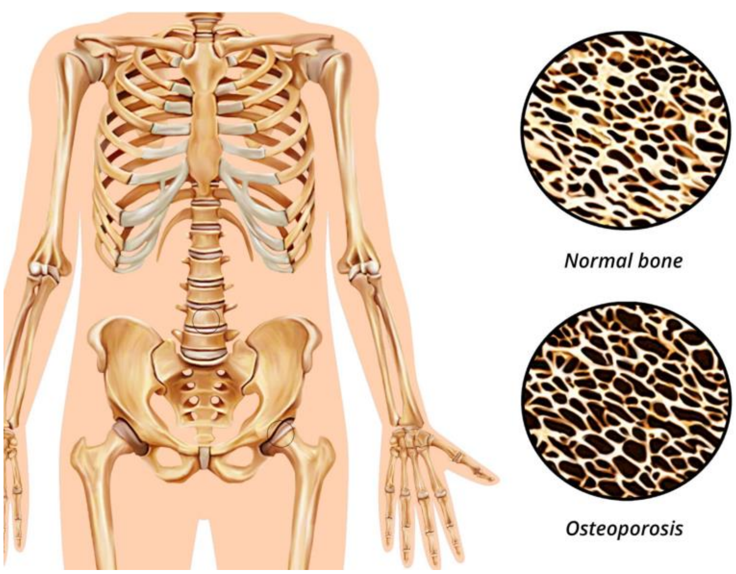
The skeletal system can be affected by disease like every other body system. Some of the main bone and joint diseases relevant to personal training are:

- Osteoporosis
- Arthritis
- Osteoarthritis
- Rheumatoid arthritis

Osteoporosis

Osteoporosis is a disease that causes bone mass to become critically low, increasing the risk of bone breaks. Osteoporosis happens more commonly in women post-menopause, although it can affect anyone at any age.

Proper nutrition can assist in the prevention of osteoporosis. This includes intaking enough dietary calcium under the supervision of a registered dietician and building bone through weight bearing exercise. Treatment for osteoporosis includes both medications and weight-bearing exercise to rebuild some of the lost bone.[1]



Arthritis

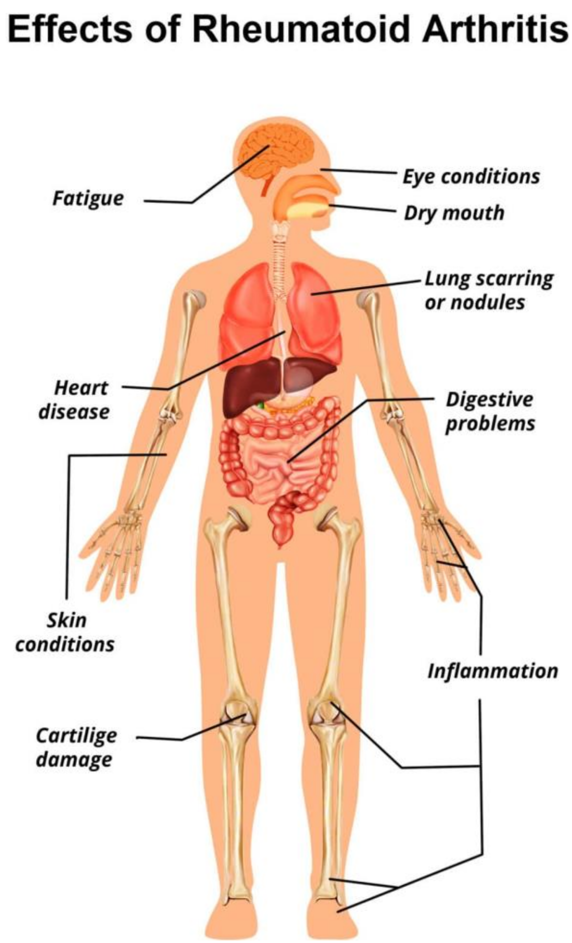
Arthritis is a common disease found in the joints characterized by pain and inflammation at the location of each affected joint. There are two kinds of arthritis commonly encountered on the gym floor: osteoarthritis and rheumatoid arthritis. Both diseases cause damage to the joint.[1]

Osteoarthritis

Osteoarthritis is the more widespread form of the disease and more frequently seen in older populations; however, individuals of any age are susceptible. Cartilage at the affected joint site has worn down leading to bone injury at the surfaces of the bones. Osteoarthritis is treated with medication and exercise. However, osteoarthritis pain can sometimes increase with sustained activity, so exercise should cease the moment if it becomes too painful.

Rheumatoid Arthritis

Rheumatoid arthritis is an autoimmune disease where the body's immune system attacks the joints. It can affect anyone at any age, but disproportionately affects women. Rheumatoid arthritis is also treated with medication and exercise. Typically, rheumatoid arthritis pain lessens with sustained activity.


Effects of Rheumatoid Arthritis
Fatigue
Eye conditions
Dry mouth
Lung scarring or nodules
Heart disease
Digestive problems
Skin conditions
Inflammation
Cartilige damage

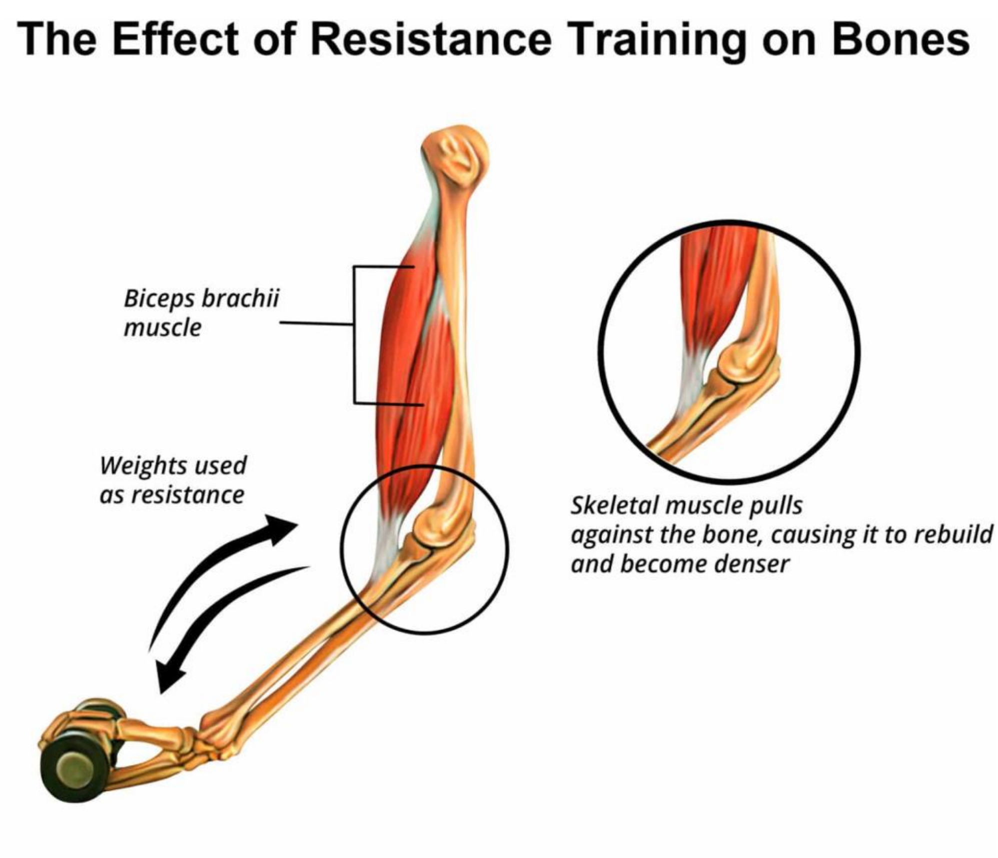

Healthy joint
Osteoarthritis
Rheumatoid arthritis

Exercise and the Skeletal System

The theory of Wolff's Law applies to exercise as it does any other external stressor. Any weight-bearing exercise adds outside stress to the body. Therefore, progressing with any form of weight-bearing exercise will increase bone mass.

Cardiovascular exercise such as running or walking also adds outside stress to the body and can increase bone mass when performed consistently over time. Strength training is one of the most effective stimuli to increase total bone mass due to the ability to load the axial spine very effectively.

The degree of bone mass increase will vary based on the type of exercise and how much stress it places on the bones.[3] Any weight-bearing exercise helps prevent osteoporosis and bone breaks, especially as clients age. The denser the bones, the more difficult it is for bones to break.[1,3]



Summary

The adult skeletal system consists of 206 bones of various sizes, shapes, and structures that support and protect the body. The system is divided into the axial and appendicular skeleton.[1] The main types of bones are long bones, short bones, flat bones, and irregular bones. Each of these bones has markings that include depressions, projections, and surfaces.[3]

Each bone is covered by periosteum. Long bones contain a diaphysis that separates two epiphyses.[3] All bones adapt to outside stressors through the work of osteoblasts and osteoclasts as described by Wolff's Law.[1]

Tendons and ligaments also help make up the skeletal system. Joints made of two or more bones (and sometimes ligaments) connect the skeletal system and allow for range of motion. Non-synovial joints help protect organs while synovial joints such as gliding, ball–and–socket, pivot, hinge, saddle, and condylar joints allow for movement.[1,2,3]

Diseases affecting the skeletal system include osteoporosis, osteoarthritis, and rheumatoid arthritis.[1] As predicted by Wolff's Law, the skeletal system will increase bone mass as an adaptation to many different types of exercise, since exercise causes external stress on the body.[3]

Improvements to bone mass and the subsequent ability of bones to withstand more force before breaking are key benefits of exercise that occur within the skeletal system in response to training with external resistance.

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Chapter 2

The Nervous System

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Introduction to the Nervous System

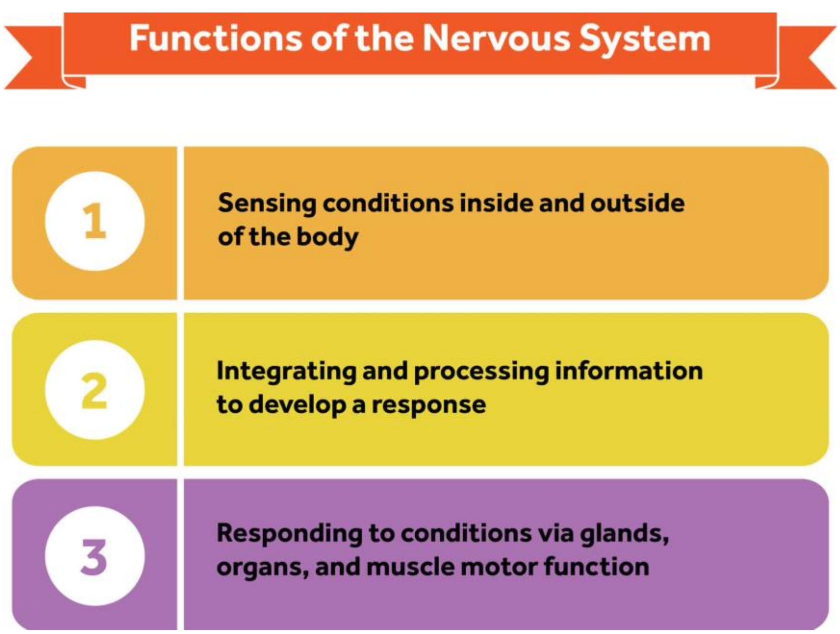
The nervous system offers three main functions:

1. Senses conditions inside and outside the body, which allows it to take in sensory information.
2. Integrates the information by sorting it out and forming a response.
3. Carries out the response through glands, muscles, and other organs via its motor function.[3]

A special function of the nervous system important to fitness and exercise is proprioception. Proprioception, or kinesthetic perception, allows the body to detect its location in the environment. Proprioception also assists in detecting the locations of the different limbs and other areas in relation to one another.[2]

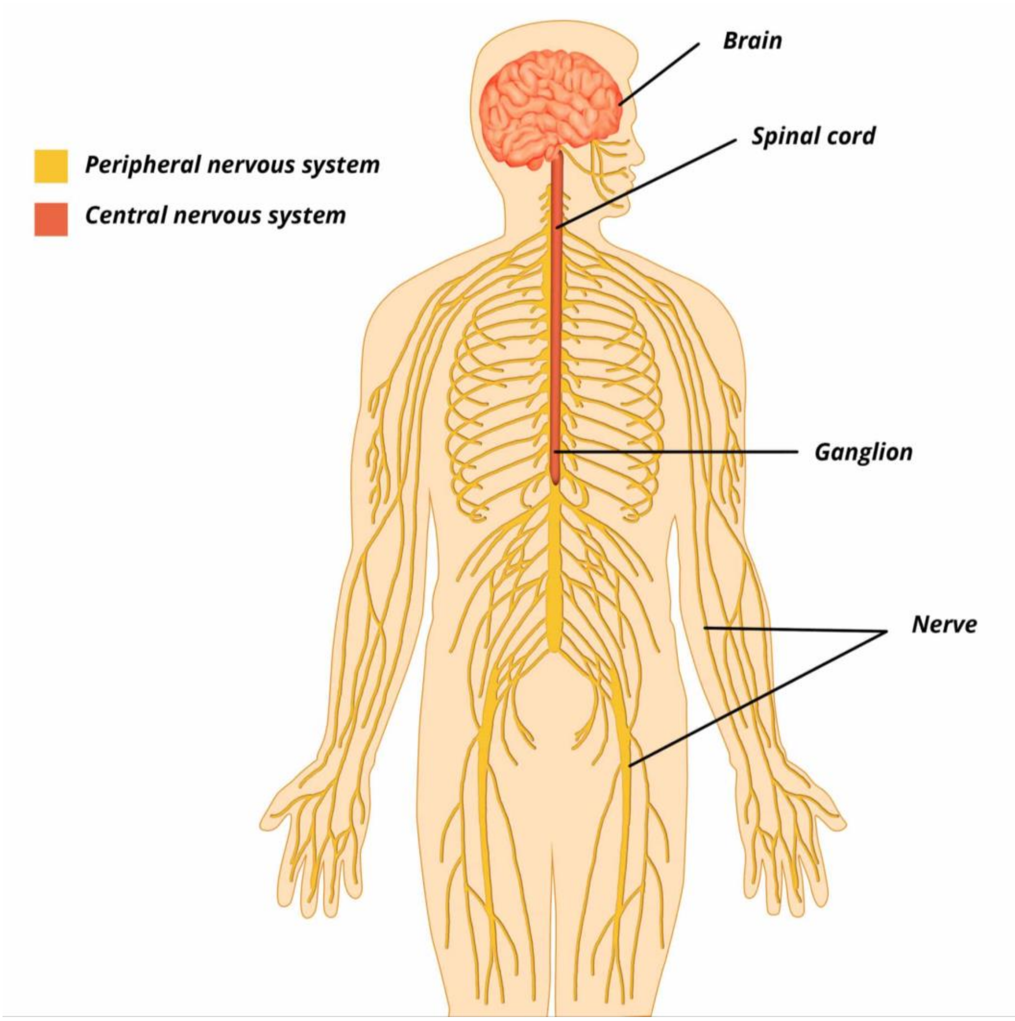
The receptors that provide this information are called proprioceptors. They are found in the tendons, joints, and muscles as well as parts of the ear (the vestibular system).1 It is important for the body to have this awareness when exercising in order to perform movements correctly and avoid injury.[2]

If a person stands on one foot, their nervous system intakes information via proprioception to keep them balanced. Proprioceptors in the joints, muscles, tendons, and ears take in information to locate the body for proper balance. Through the nervous system's awareness of location in relation to the environment and the body's parts in relation to one another, balancing on one foot becomes possible.



Divisions of the Nervous System

Two biggest divisions of the nervous system are the central nervous system and the peripheral nervous system.



Central Nervous System (CNS)

The central nervous system, or CNS, includes the brain and spinal cord.[1] The brain is located inside the skull.[1] The human adult brain on average weighs a little more than three pounds.[3] The spinal cord is found inside the vertebrae.

It sends messages to the brain or participates in reflexes in which the brain is not required.[1] The central nervous system is where the nervous system performs its integrative functions.

Peripheral Nervous System (PNS)

The peripheral nervous system, or PNS, contains neurons and neuroglia outside the brain and spinal cord.[1] The peripheral nervous system allows the CNS to communicate with the rest of the body and vice versa. It is the location for the sensory and motor functions of the nervous system.[3]

Sensory Division

The peripheral nervous system divides into sensory and motor divisions. The sensory division of the peripheral nervous system is also known as the afferent nervous system. It sends messages from receptors to the central nervous system via axons.[3]

Motor Division

The motor division of the peripheral nervous system sends messages from the central nervous system to glands, muscles, and other organs. It is also referred to as the efferent nervous system. This motor division divides even further into the somatic and autonomic nervous systems.[3]

Somatic Nervous System

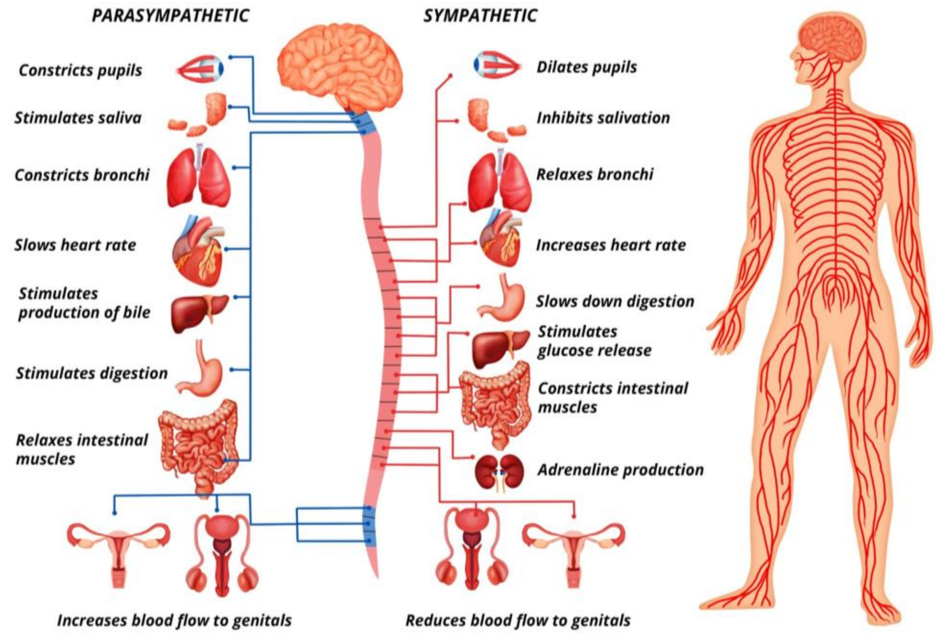
The somatic nervous system transmits impulses to the musculoskeletal system as well as the eyes, skin, and ears.[1] It controls voluntary muscle, which describes muscle that is controlled by conscious thought.[3]

For example, the somatic nervous system tells the muscles to contract and relax, allowing a person to perform a biceps curl. The somatic nervous system is important especially in the function of muscles during exercise and activity.

Autonomic Nervous System

The autonomic nervous system deals with glands as well as involuntary muscle, also known as smooth muscle and cardiac muscle.[1] The autonomic nervous system does not function consciously. It allows the heart rate to change or the blood pressure to go up and down along with many other unconscious body adaptations.

Therefore, this system is also very important during exercise. It is divided into the sympathetic nervous system and the parasympathetic nervous system.[3]



Sympathetic Nervous System (SNS)

The sympathetic nervous system (or SNS) helps the body focus on physical activity. It tells the body to focus blood on the muscles and heart rather than the skin. It also helps increase airflow to the lungs and allows the liver to release glucose from its glycogen stores. It creates many more responses in addition to those just mentioned.[2] Essentially, the sympathetic nervous system primes the body for "fight or flight" responses, including during exercise.

Parasympathetic Nervous System (PNS)

The parasympathetic nervous system (or PNS) is also known as the "rest and digest" nervous system. This is the part of the nervous system that controls certain unconscious body functions when the body is at rest. It promotes digestion. Some of its other effects include a lowered heart rate and bronchoconstriction (an effect in the lungs that decreases airflow).[2]

Neurons

The two basic units of the nervous system are neurons and neuroglia. Neurons send messages via electrical impulses throughout the body. They are also known as nerve cells. Neuroglia, also known as glial cells, are the supporting cells of the neurons. Often they also have special functions depending on their specific type.[3] Neurons have the most direct effect on the body's functioning during exercise.

Neurons generally cannot regenerate; therefore, they have long lifespans. Many survive as long as the human they reside in. However, this also means if someone injures their neurons, permanent damage could occur.

Because they are constantly sending messages, neurons require lots of oxygen and energy. They quickly die if oxygen supplies deplete.[3] Neurons contain a cell body and processes. The cell body receives messages from other neurons or receptors and holds the nucleus of the cell and most other organelles. Sometimes the cell body is referred to as the soma or perikaryon.[3]

Processes are extensions of the cell. These include dendrites and axons. Dendrites collect the impulses to convey to the cell body, whereas axons send the message from the cell body to other cells. Often, axons send messages to another nerve and sometimes they send messages to a muscle or a gland or another type of tissue. The neuron axon can be surrounded by a myelin sheath. The myelin sheath both protects the axon and allows for quicker conduction of impulses.[3]

Types of Neurons

There are multiple ways scientists classify neurons. One distinction scientists use to classify is the number of poles or processes the neuron has. All neurons only have one axon, but the number of dendrites varies.

Multipolar Neuron

A multipolar neuron contains one axon and multiple dendrites. This is the most common type of neuron. Motor neurons are usually multipolar.[3] For example, a nerve controlling latissimus dorsi muscle movement is multipolar.

Bipolar Neuron

A bipolar neuron has one axon and one dendrite. It is found in organs that pertain to special senses such as the nose.[3]

Unipolar Neuron

A unipolar neuron has one axon with two branches. It does not contain dendrites. Most unipolar neurons are sensory, especially sensory neurons in the peripheral nervous system that extend into the central nervous system.[3]

Sensory Neuron

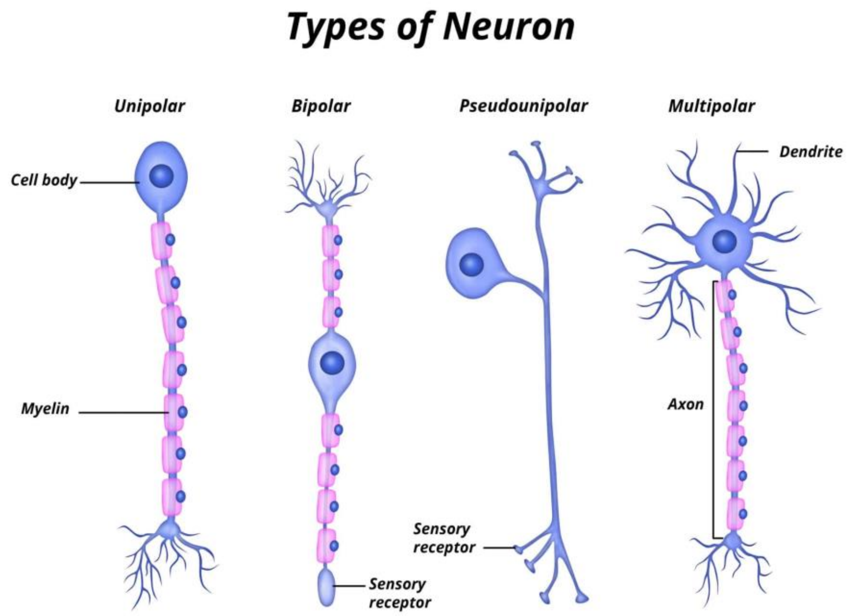
A sensory neuron takes in information and transmits the information to the central nervous system. Most sensory neurons are unipolar, however sometimes they are bipolar. A sensory neuron includes a nerve such as one that senses pain, or a nociceptor, like those on fingertips that sense a coffee cup that is too hot upon touch.[3]

Motor Neuron

A motor neuron sends information from the central nervous system to organs such as the muscle. Most are multipolar neurons.[3] The latissimus dorsi muscle described above as multipolar is classified as a motor neuron.

Interneuron

An interneuron conveys information between the sensory nerves and motor nerves. Like motor neurons, most interneurons are multipolar.[3] One can think of the interneurons as the necessary middlemen for most body responses to the environment.

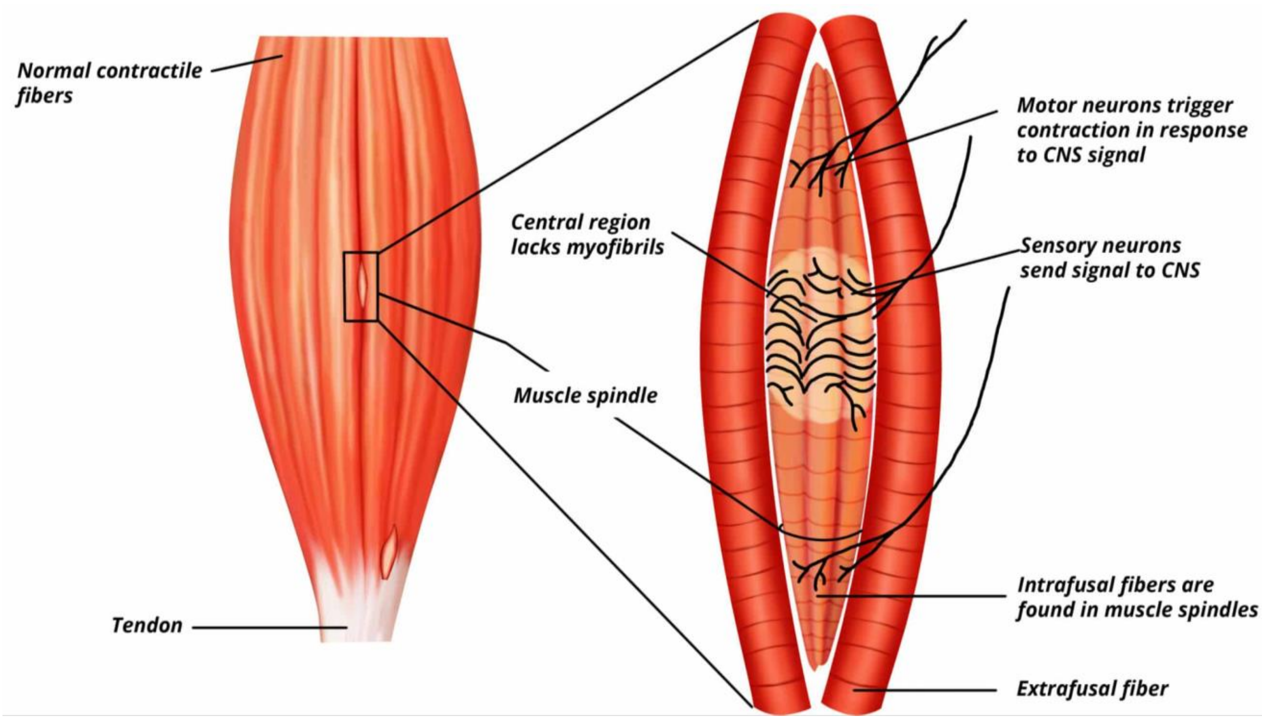


Sensory Receptors

Sometimes instead of having just a simple sensory neuron, the body uses sensory receptors to sense the internal or external environment. These receptors input to the central nervous system or they have mechanisms for more local reflexes.[3] These special sensory receptors act in ways specific to exercise and fitness.

Muscle Spindles

Muscle spindles are specialized fibers running parallel to muscles that are stimulated when stretched and serve to recognize the length and rate of change in a muscle and trigger a muscle contraction in response. They are designed to protect muscles from being overstretched and they also assist in plyometric activities.

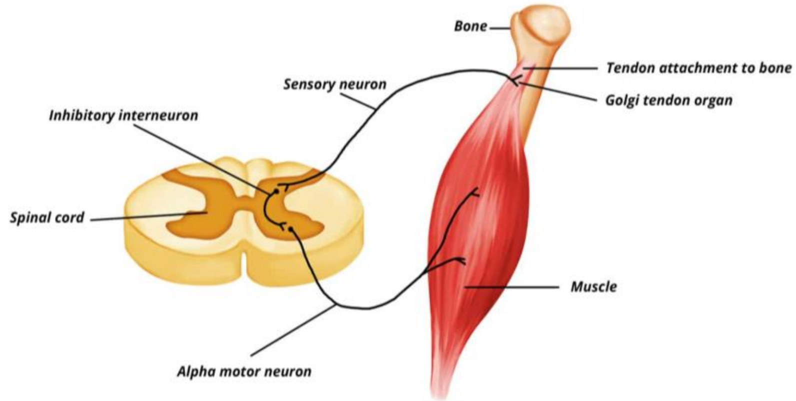


If a muscle spindle recognizes the muscle is overstretched, a reflex occurs when the overstretched muscle contracts to protect from injury and to keep muscle tone.[2] Muscle spindles are located in perimysium to allow for a quick local response.[3]

Golgi Tendon Organs

Golgi tendon organs sense excessive tension in the muscles and trigger a relaxation response.[2] They are located where the muscles attach to tendons and protect the muscles and tendons from tearing due to excessive muscular tension. If there is too much stress placed on the muscles, the Golgi relaxation reflex results in involuntary muscular relaxation.[3]

Joint receptors are found in synovial joints.[3] They react to pressure which allows the body to sense how the joint is positioned, aiding in proprioception.[2] For example, a joint receptor will aid in allowing the body to know where the elbow is located throughout a golf swing.

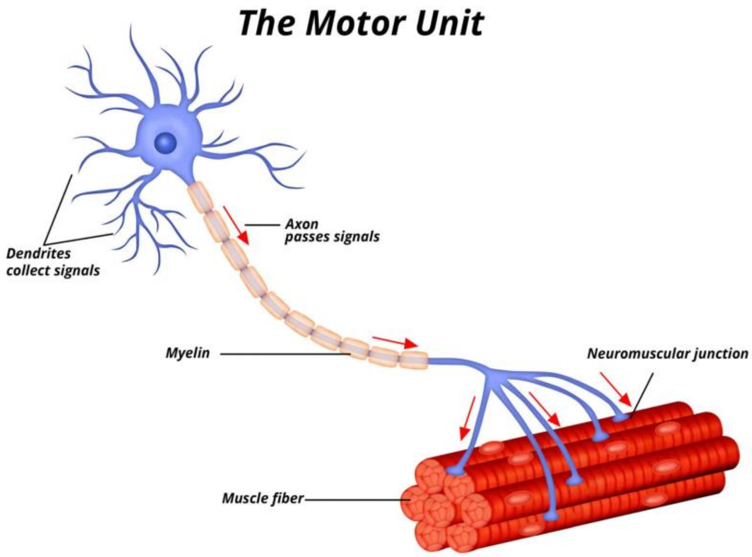


Physical Activity and the Nervous System

The nervous system participates in physical activity and the way in which the body adapts to movement immediately and over time. Motor units are the key component of the nervous system that allows all human movement. The motor unit includes one motor neuron plus the muscle fibers it innervates. One neuron in a motor unit can innervate four or more muscle fibers.

Motor units in smaller muscles that perform more meticulous movements (such as threading a needle) often contain a neuron that is attached to fewer muscle fibers than those attached to larger muscles. Larger muscles contain motor units with a large number of muscle fibers per motor neuron.[2]

Motor neurons discharge an action potential across the neuromuscular junction, stimulating muscular contraction in all muscle fibers within the motor unit.



This contraction process follows the all-or-nothing principle, which states that when a motor neuron discharges its potential, every single muscle fiber in its motor unit contracts without any possibility of fractional stimulation. The motor unit is either completely stimulated or does not contract at all.[2]

In order to move a muscle, the recruitment of motor units must occur. Motor unit recruitment is the sequence of activation of a particular pattern of motor units for a movement. The efficiency of motor unit recruitment is one of the multiple factors that affect how much force the muscle can develop.[4]

Recruitment of motor units begins with those that contain slow twitch muscle fibers. If a large enough force is required, fast-twitch muscle fibers are then recruited. Even at maximum muscle force, not all muscle fibers in a muscle typically join in in order to avoid injury in both the tendon and muscle.[2]

More recruitment is required for shortening muscle than lengthening muscle with the same amount of force.[4] In terms of the strength of overall motor recruitment, the muscles can increase both the number of motor units recruited and improve the efficiency in the pattern of fibers recruited.[2]

Another major factor that determines acute muscle force is rate coding. Rate coding refers to the frequency at which the action stimulates the motor unit. Increased rate coding results in increased muscle force development and is one of the nervous system adaptations that improve muscle force capability.[4]

Over time, rate coding changes based on adaptations to training. Strength training is more likely to increase the rate coding in the muscles being trained. Endurance training is likely to decrease rate coding because improved muscular conditioning means fewer muscle contractions are required to maintain a given intensity.

Essentially, the rate coding increases in strength training to allow for an increase in maximal force whereas the rate coding may decrease in some cases in endurance training as the body becomes more efficient at endurance movements.[4] If a person decreases their activity level, their muscles will decrease their rate coding over time.[4]

Motor unit synchronization happens when multiple motor units activate at the same time. This is another factor that affects the neuromuscular system. Studies have shown that strength training increases motor unit synchronization. This most likely benefits the rate of force production as well as allowing for better coordination.[5]

For example, when an athlete practices weighted lunges over a training period, their motor units begin to synchronize with each other, allowing them to lunge more effectively and with coordination. Their movement becomes more refined and their muscle fibers engage more collectively. They may also be able to lift more weight in the movement thanks to the improved synchronization.

Overall, the increased recruitment, rate coding, and improved synchronization are all nervous system adaptations that lead to improved strength and performance in physical activity, independent of adaptations in other body systems.

Summary

The nervous system senses, integrates, and responds to stimuli both internally and externally.[3] One of its main functions in relation to exercise includes proprioception, allowing the body to sense where it is in relation to the outside and inside environment.[1,2]

The nervous system contains multiple subdivisions starting with the central and peripheral divisions.[1] The peripheral nervous system is further divided into the sensory and motor divisions. The motor division is then divided into the somatic and autonomic divisions.[3]

Finally, the autonomic division is divided into the sympathetic and parasympathetic nervous system.[2]

The nervous system contains neurons that send messages throughout the body, and neuroglia, that support the neurons. Each neuron is made up of a cell body and processes that allow messages to be received and sent through electrical impulses. The neurons can be classified by number of poles as well as their function.

Sometimes, multiple nerves and other supporting cells make up special receptors. These include muscle spindles, Golgi tendon organs, and joint receptors.[2] These receptors help the body function during exercise.

The nervous system allows movement to occur via motor units that innervate the muscle. These motor units are recruited in different numbers and different patterns for different forces.[2] There is some evidence that the recruitment motor unit number changes with different forms of exercise.[5] Rate coding is the frequency at which the motor units are stimulated. Rate frequency appears to increase with strength training and decrease with endurance training.[4]

Motor unit synchronization allows multiple motor units to fire at the same time. Strength training potentially increases the level of motor unit synchronization, as well as rate coding and recruitment, which are among the key performance adaptations that occur in the nervous system in response to resistance training.[5]

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Chapter 3

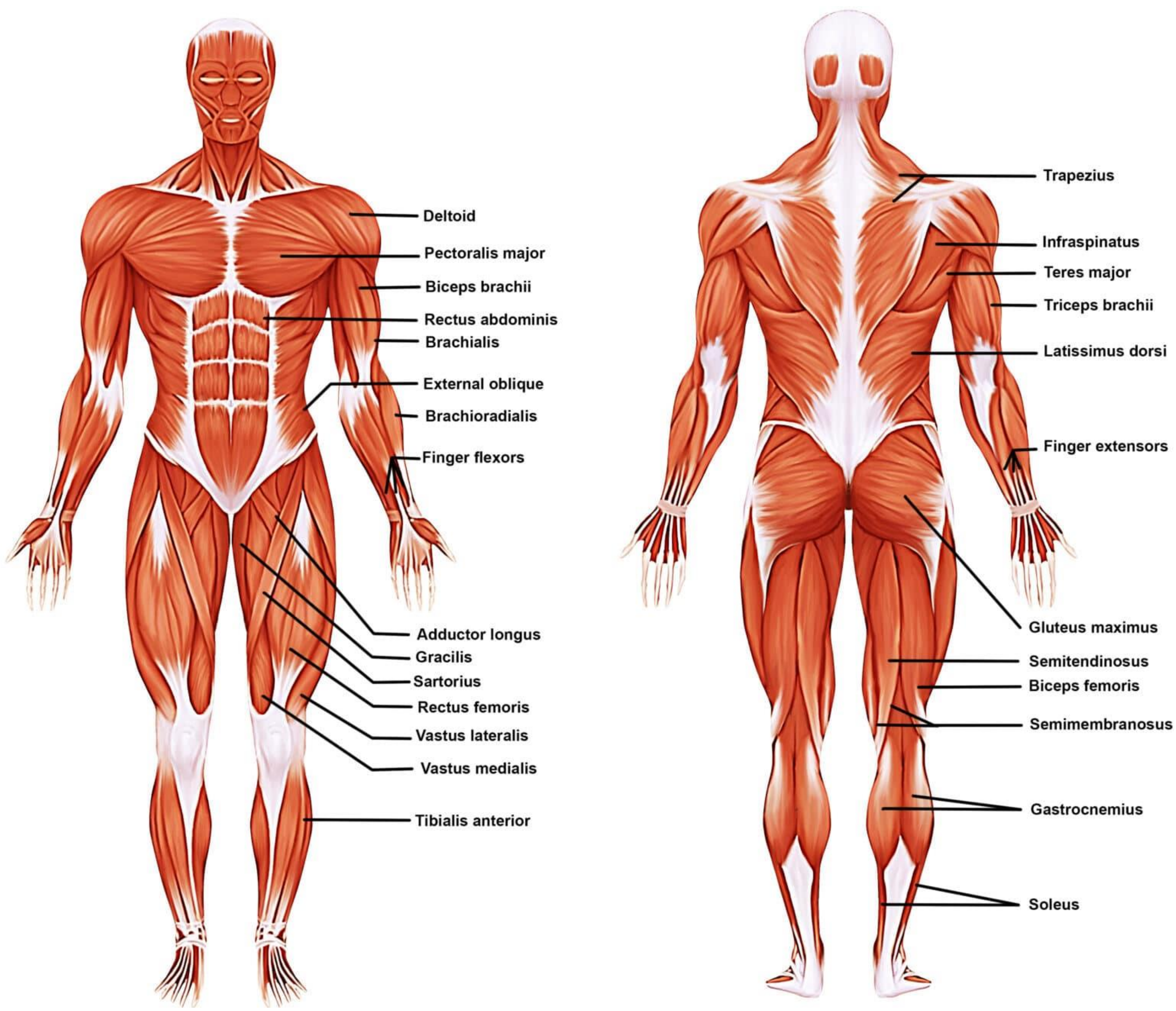
The Muscular System

Tyler Kettle, MS

Introduction to the Muscular System

The architecture of skeletal muscle is composed of both macro- and micro- structures that interact during muscle contract to shorten the length of the muscle, pulling on the bone across the joint, resulting in movement of the bone with the joint as the pivot point.

Having a strong grasp of the structure and function of skeletal muscles is important for fitness professionals to understand the biological processes behind resistance training, including muscle contraction. This knowledge both helps guide programming considerations as well as competently explain to a curious client exactly what goes on behind the scenes in the human body during motion.



Muscle Macrostructure

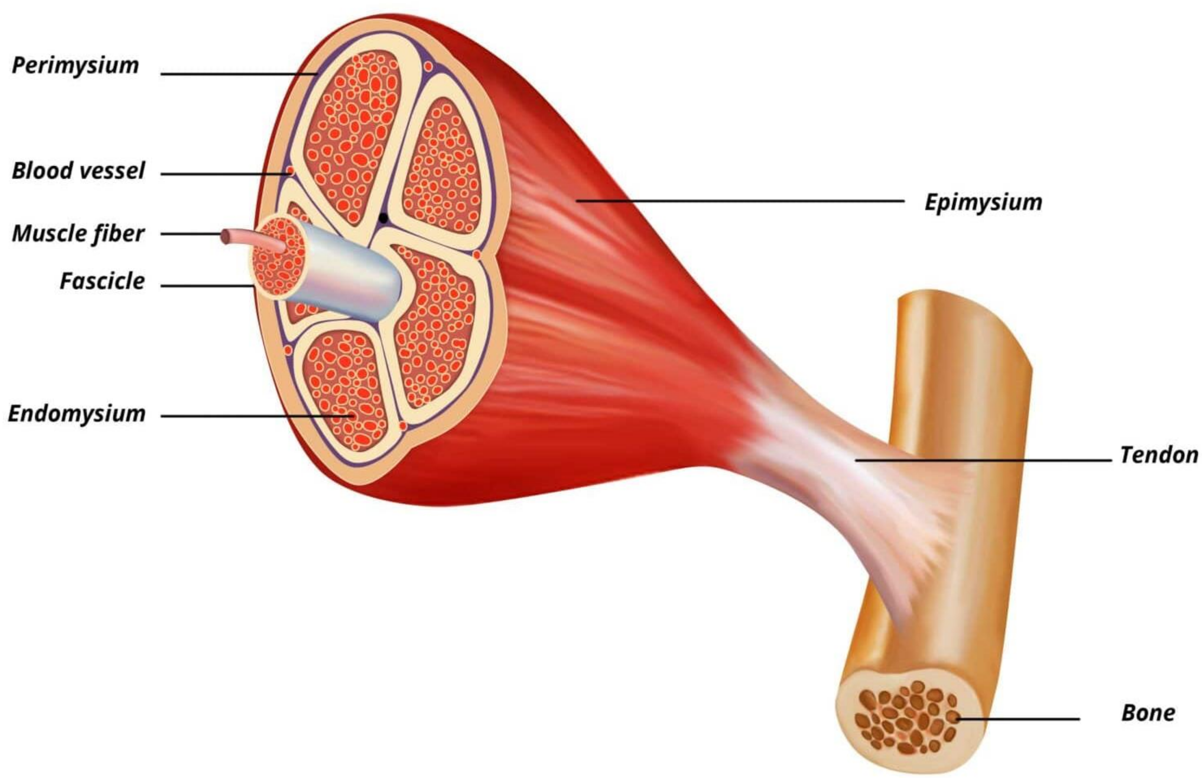
Closer examination reveals that muscle consists of a series of grouped bundles.

A layer of connective tissues surrounds the entire muscle, called the fascia, with the outer layer called the epimysium. This fascia surrounds a series of bundles known as fascicles.

Each of these fascicles creates the main belly of the muscle. Outside individual fascicles is another outer layer of connective tissue called the perimysium.

In skeletal muscle, muscle fibers contain a nucleus and striations, giving them their sinewy appearance.

Muscle structure also includes mitochondria, the sarcoplasmic reticulum, and the endoplasmic reticulum. These organelles live inside the sarcolemma, a layer of cell membrane directly underneath the endomysium.[3]



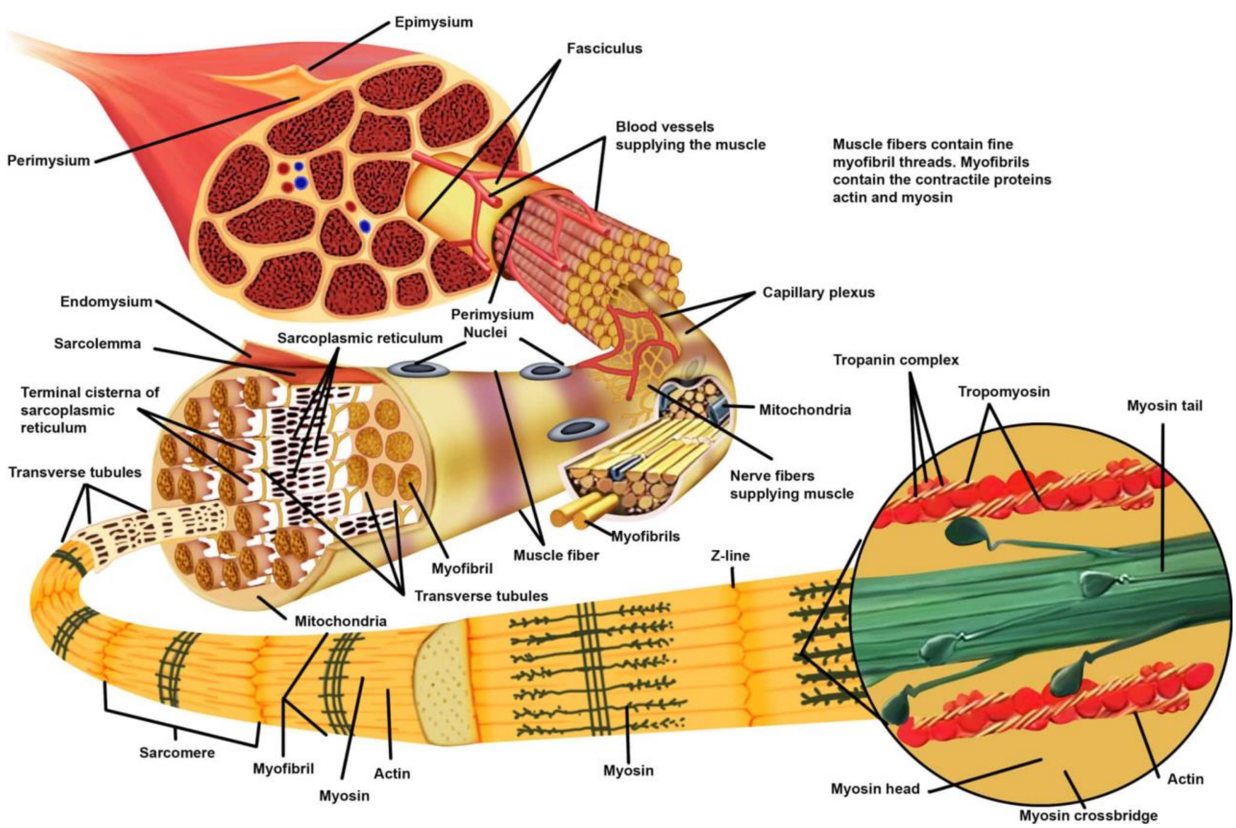
Muscle Microstructure

Inside the sarcolemma, several microstructures exist that help and allow the muscle fiber to operate as a functional unit. The mitochondria help facilitate energy creation inside the body, and the ability for muscles to contract. Striated muscles also contain nuclei. Nuclei act as control centers for individual cells. Without a nucleus, skeletal muscle has no action potential and no contraction.

Along the sarcolemma is a channel known as the t-tubule, or transverse tubule, which releases calcium into the sarcoplasmic reticulum in response to motor unit stimulation. The calcium ions play a key role in triggering muscle contraction.

These structures are all located around the long cylindrical structure known as myofibrils. Bundled myofibrils create muscle fibers. Contractile units called sarcomeres make up the myofibrils.

The sarcomeres themselves contain the smallest muscular structures, protein filaments known as actin and myosin. When forces pull actin and myosin together, the distance shortens between ends of sarcomeres, known as "Z" lines, creating a muscular contraction.[3]



Sliding Filament Theory

The sliding filament theory describes the mechanisms of muscular contraction. As mentioned above, contractile proteins actin and myosin live within the sarcomere of a muscle fiber.

Actin, the thin filament, is primarily located in the I-Band. Myosin filaments, which are thicker, are primarily located in the A-Band. These two bands sit in an area from Z disc to Z disc. These Z-discs correspond to the end of each sarcomere. When these filaments pull together within the sarcomere, this creates the H-Zone, the area of overlap.2, 3

In a resting state, the filaments are blocked from binding to one another by a protein called tropomyosin. Wrapped around actin, tropomyosin prevents cross bridges from forming by blocking myosin tails from reaching up and binding with actin.

When a motor neuron discharges its action potential, a series of steps occur that result in the shortening of the sarcomere. This action potential travels from the brain to the desired muscle, signaling for contraction. At this point, the sarcoplasmic reticulum releases calcium ions into the sarcomere. The calcium binds with troponin sites and causes a rotation of the tropomyosin or actin. When these are rotated, new attachment sites become available for myosin to create a cross bridge.

ATP, adenosine triphosphate, is the energy source at the cellular level. If enough ATP is present in the sarcomere, the tails of the myosin filament now attached to actin at the cross bridge site will pull on the actin filament, causing a shortening of the I-Band, bringing the Z-discs closer together.

When this action repeats it creates a larger H-zone, the area of overlap, until no more calcium or ATP is present, requiring another action potential to release more if needed.2 During this process, the ATP loses a phosphate group and becomes adenosine diphosphate (ADP). The ADP can provide an additional phosphate group as well, further reducing it to adenosine monophosphate. However, the bulk of the phosphate required for muscle contraction comes from ATP.

This overall process of cross bridging results in shortening across the sarcomeres in the muscle that is contracting. The result is a shortening of the overall muscle, a pulling force on the bone, and the resulting movement about the corresponding joint.

Energy Systems

ATP is required for all muscular actions and gets broken down during the course of muscle contraction. As such, the replenishment of ATP is the primary goal of the energy systems in the human body.

The body's energy systems include both anaerobic and aerobic methods of ATP replenishment. Anaerobic methods do not require oxygen and typically supply energy for higher-intensity activities. Anaerobic energy production is limited in duration and requires rest between bouts of activity to sustain the high intensity.

Aerobic energy requires the presence of sufficient oxygen in the muscle cell to metabolize glucose and fat and break down ATP. Aerobic energy production is limited by the ability of the body to use and supply oxygen to working tissues. When the work capacity exceeds the availability of oxygen in working tissues, the muscles shift to anaerobic energy. While the aerobic system cannot supply ATP for very high intensity exercise, it can sustain ATP virtually indefinitely if oxygen and either glucose or fat are present in the cell.

The three main systems of the body are the ATP-PC, glycolytic, and aerobic systems. The ATP-PC system is entirely anaerobic. The glycolytic system has the ability to function anaerobically or aerobically depending on intensity. The aerobic system depends on the presence of oxygen to function.

In every human activity, each system contributes to ATP production to some degree. The intensity of the activity will determine which energy system plays the biggest role in replenishing ATP.

ATP-PC System

The ATP-PC system supplies energy for high intensity, short duration activities. It relies on limited intramuscular supply of phosphocreatine (PC) as a rapid source of ATP. The PC supplies the phosphate to rephosphorylate ADP into ATP, and becomes free creatine in the process.

This energy system rapidly yields a high quantity of ATP until PC stores are depleted. At this point, the body must reduce intensity to allow the glycolytic or oxidative systems to replenish ATP and rephosphorylate the free creatine back into phosphocreatine.

The ATP-PC system supplies the vast majority of energy during maximal intensity exercises lasting less than 10 seconds such as Olympic lifting, powerlifting, and short-distance sprints.

The Glycolytic System

The glycolytic system relies on glucose and glycogen for the energy to replenish ATP. Anaerobic glycolysis occurs when the body breaks down glucose or glycogen without any oxygen present.

While anaerobic glycolysis can rapidly replenish ATP stores during high intensity exercises lasting 10-30 seconds, lactate and H^+ ions are produced as a result and cause a drop in cellular pH, which is associated with muscle fatigue and the need to reduce intensity. Lactate itself is not responsible for the burning sensation associated with muscle fatigue, but the buildup of lactate occurs concurrently with the fatigue.

Following intensity reductions or muscle failure, oxygen levels can rise enough to allow clearance of lactate and reliance on aerobic energy.

The Mitochondrial Respiratory System (Oxidative)

For exercise lasting longer than 30 seconds, the body will begin a shift to aerobic glycolysis and the aerobic system. This energy system can sustain ATP replenishment for much longer because the body can use oxygen to metabolize the by-products of glycolysis before they convert to lactate and drop cellular pH.

The extra metabolic steps mean the rate of ATP production is lower than in anaerobic glycolysis. However, the avoidance of lactate buildup means that aerobic glycolysis can be sustained for longer.

Exercise that lasts longer than 3 minutes will be fueled almost entirely by the aerobic energy system. Trained athletes can exercise at absolute intensities much higher than the general population while still relying on aerobic energy. As such, fitness level plays a large role in determining whether a certain absolute intensity will require the addition of anaerobic energy.[3]

Muscle Fiber Types

Skeletal muscles in the human body are typically classified into two main muscle fiber types: type I and type II. Different muscles throughout the body will display different muscle fiber types.

Each of these types of muscles will be classified with three types of criteria:

1. Movement rates
2. Responses to neural signaling
3. Metabolic styles

Type I (Slow Twitch)

Type I muscle fibers are classified as such because they rely on oxidative or aerobic metabolism. Type I muscles thrive on the ability to use oxygen to resupply energy, meaning that type I muscle fibers are primed to perform exercise or physical activity at a much slower rate.

This means type I muscle fibers do not fatigue as quickly and can perform muscular action for much longer. The act of walking is an excellent example. From an early age, most humans can walk for extended periods of time without the muscles of the legs fatiguing. This is due to the slow twitch nature of the muscles in the leg and the body's ability to utilize oxygen as an energy source.

Type II (Fast Twitch)

Type II muscle fibers rely first-and-foremost on the ATP-PC and glycolytic systems. Type II muscle fibers generally have a greater maximal force output when compared to type I fibers but are quicker to fatigue. Type II fibers are further broken down into type IIa and type IIx fibers.

Type IIa

Type IIa muscle fibers are an intermediate fiber type. Type IIa muscles have a high capacity for anaerobic energy but have greater aerobic and glycolytic capacity than type IIx fibers.

Type IIx

Type IIx muscle fibers rely primarily on the ATP-PC system for energy. They are capable of the greatest force production but also have the least resistance to fatigue.[5, 3]

Muscle Fiber Type Characteristics

Characteristic	Type I Fibers	Type IIa Fibers	Type IIx Fibers
Fiber diameter	Small	Medium	Large
Capillary density	High	Medium	Low
Myoglobin content	High	Low	Low
Motor neuron size	Small	Large	Large
Fatigue resistance	High	Medium/Low	Low
Relaxation speed	Slow	Fast	Fast
Contraction speed	Slow	Fast	Fast
Endurance	High	Medium/Low	Low
Force production	Low	Medium	High
Power output	Low	Medium/Low	High
Anaerobic enzyme content	Low	High	High
Aerobic enzyme content	High	Medium/Low	Low
Sarcoplasmic reticulum complexity	Low	Medium/High	High
Mitochondrial size	High	Medium	Low
Color	Red	White/Red	White

Muscular Adaptations to Exercise

Adaptations to exercise occur in the muscular system over time based on the type and intensity of activity. Anaerobic activities lead to adaptations within the muscle tissue that further improve their ability to produce force anaerobically.

Aerobic training, on the other hand, leads to adaptations that improve the oxidative capacity of muscles due to the duration and intensity of an exercise. These muscles require continuous training to adapt over time and can be reversed with inactive states.[6]

Resistance Training Muscular Adaptations

The typical change expected from resistance training is a change in the force production capability and cross-sectional size of the muscles. Resistance training causes a series of micro-tears at the level of the sarcomeres.[4] The healing of those tears is how the muscle cells specifically adapt strength and size in response to resistance training.

Cross-Sectional Area

In resistance training one of the main adaptations is increased cross sectional area. This occurs over time when the series of microtears seen in the sarcomere of a muscle fiber heal and that healing compacts on itself. The body has the ability to build up the areas of frequent breakdown to handle the stress put on the muscles by an external weight. This build up over time increases cross sectional area, making muscles larger and more defined.[7]

Strength

Another definable adaptation that occurs with resistance training is increase in force production. Increases in strength and force production mainly occur in response to the increase in cross sectional area. With a larger cross-sectional area, more area becomes available to overlap the protein filaments actin and myosin, resulting in a greater potential for force production.

Aerobic Training Muscular Adaptations

Muscular adaptations to aerobic training improve the fiber's ability to supply and use oxygen during aerobic exercise.

Increased Capillary Density

After consistent, progressive aerobic training, the body increases the number of capillaries that surround a muscle. Capillaries are the body's exchange site for blood and other crucial nutrients. These extremely thin exchange vessels wrap around the skeletal muscle, providing a dropoff site for the muscles to receive and utilize delivered nutrients.

This effect provides increased blood flow and increased surface area. With a larger surface area, a greater area of the muscle is covered by capillaries, creating a shortened travel distance for blood and nutrients to be utilized. This also upregulates the body's ability to use more oxygen and to use it more effectively.[6]

Increased Mitochondrial Density

An increase in cellular mitochondria occurs with frequent aerobic training. This increase allows for the body's aerobic system to function at an increased rate, with more mitochondria able to function, creating an increased rate of fatty acid oxidation and energy production along with biochemical adaptations at the cellular level. Increased mitochondria also promote a more stable environment for type I muscle fiber endurance.[6]

Shared Adaptations

There are several adaptations that occur as a result of both resistance and aerobic training.

- Increased blood volume
- Increased cardiac output
- Lower resting heart rate
- Reduced symptoms of anxiety
- Reduced symptoms of depression
- Weight loss

Summary

Skeletal muscle is comprised of macro- and micro- structures which create movements where joints interact with bone. Sliding filament theory describes how the actin and myosin filaments cross, creating a shortening of the muscle. ATP is required for all muscle actions and is used through three different types of energy systems (ATP-PC, glycolytic, oxidative).

Different muscle fiber types correspond to these systems to produce movements over different time frames. Finally, the muscles adapt to both resistance and aerobic training modalities in specific ways to facilitate improvements for future stresses.

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Chapter 4

The Cardiorespiratory System

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Introduction to the Cardiorespiratory System

Fitness professionals must have basic working knowledge of the cardiorespiratory system for a number of reasons. Program design principles are all based on the underlying anatomy of the human body. As such, knowledge of anatomy allows fitness professionals to make better programming decisions, and explain those decisions more effectively with the client.

Furthermore, anyone working with clients must understand the acute and chronic responses of the cardiorespiratory system to ensure they can safely train clients, monitor intensity, and respond to any emergencies.

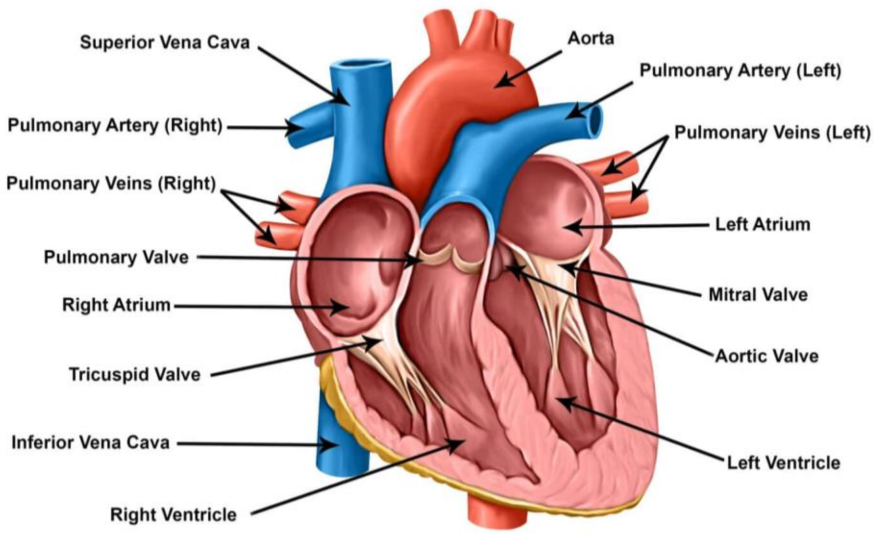
This chapter covers the basic anatomy and function of the cardiorespiratory system and its responses to exercise. The cardiorespiratory system (CRS) plays an integral role in meeting the demands of the body. The cardiorespiratory system consists of two main pieces: the pulmonary system, which consists of the airways and lungs, and the cardiovascular system: the heart, blood vessels, and blood.[3]

In totality, the cardiorespiratory system pumps oxygenated, nutrient-rich blood through miles of blood vessels. Tissues take in the nutrients and oxygen from blood while excreting waste, which is then transported by the blood for excretion.

During physical activity, the increased demand for oxygen can prompt the cardiorespiratory system to work harder by increasing breath, heart rate, and blood flow. Exercise can elicit a physiological response to the CRS so that it meets the needs of the activity.

Components of the Cardiorespiratory System

Heart



The heart is located within the mediastinum. This is a cavity within the thorax. It rests just above the diaphragm, posterior to the sternum. About two-thirds of the heart lies to the left side of the sternum line. The heart is enclosed by a double-walled sac called the pericardium.[3]

The superficial sac is the fibrous pericardium. This is a tough layer that anchors to surrounding structures and protects the heart. The serous pericardium is a thin, slippery layer that acts as a lubricant to prevent sticking. The fluid used between these two layers is called serous fluid and helps the heart operate in a low-friction environment.

The three layers of the heart are the epicardium, myocardium, and endocardium. The epicardium is the layer of serous pericardium. This layer can be replaced with fat as individuals get older. The myocardium is considered the muscle of the heart, while the endocardium lines the inside walls of the heart and blood vessels.

Cardiac muscle forms the bulk of what is considered the heart. Cardiac muscle is much different than skeletal muscle. Myocardium cells are held together by connective tissue that crisscrosses. The muscle is arranged as bundles that connect the entire heart. This ensures that when the heart contracts, the most amount of blood possible is ejected from the heart.

Lastly, the endocardium covers the entire inside walls of the heart, including the valves, chambers, arteries, and veins.

Chambers and Vessels

The heart consists of four chambers: the left and right atria and left and right ventricles. The chambers are separated by flow specific valves that open and close in perfect coordination during each cardiac cycle.

The atria are the chambers of the heart that receive blood. They are small appendages that are somewhat smooth on the outside.[3] The right atrium has bundled up muscle tissue that forms ridges called pectinate which look like small comb bristles.

The two vessels are smaller and not as muscular as the ventricles because they only need to push blood downward into the ventricles. The ventricles on the other hand need to push the blood out to the entire body and to the lungs. Blood enters the right atrium via three veins: the superior vena cava, the inferior vena cava, and the coronary sinus.

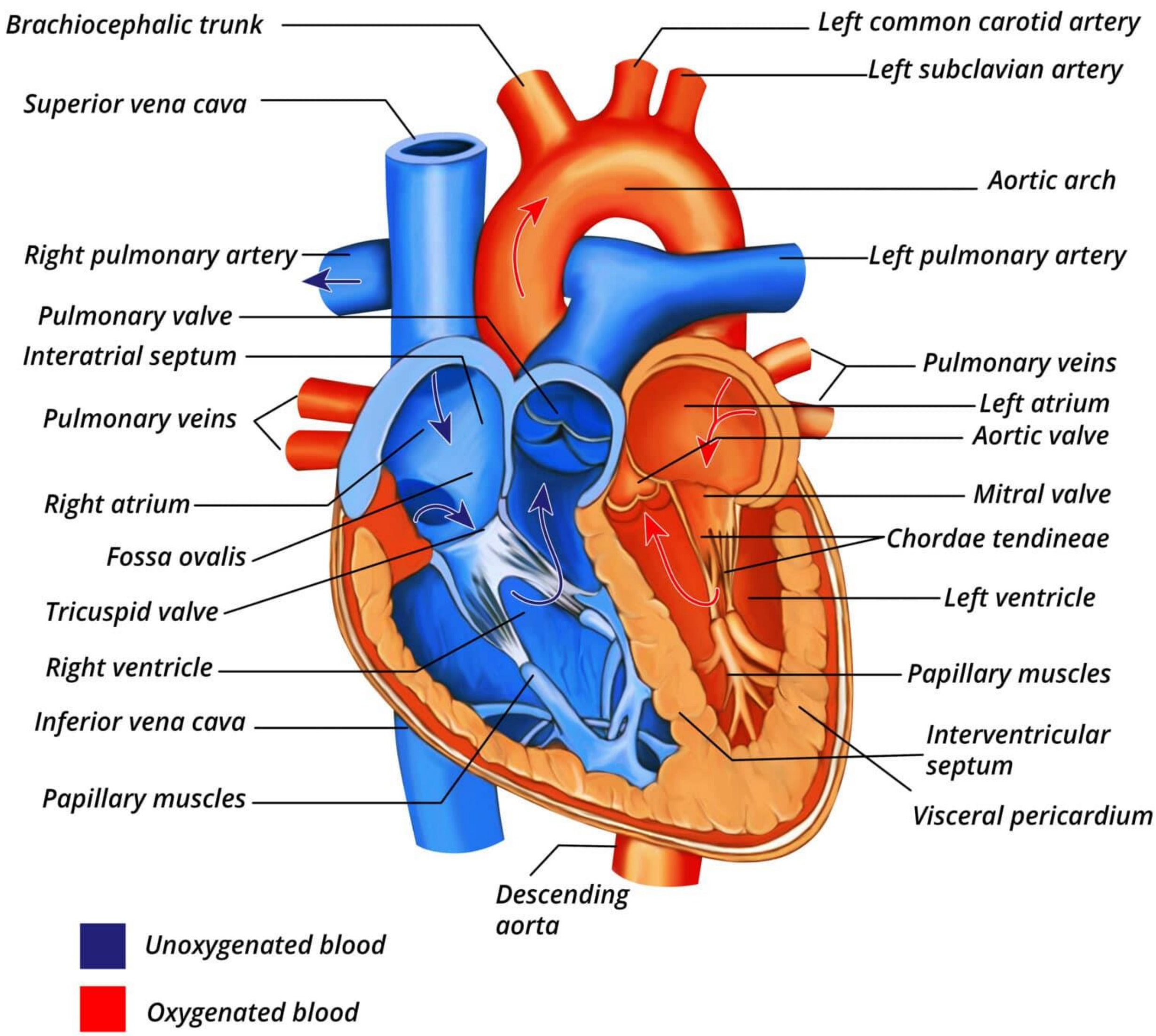
The superior vena cava returns blood from the body region that is above the diaphragm. The inferior vena cava returns blood from the body region that is below the diaphragm. Lastly, the coronary sinus collects the blood that drains from the myocardium.

The ventricles are known as the discharging chambers. The ventricles are lined with trabeculae carneae, which look like irregular ridges. The walls of the ventricles are much thicker than the atria. The right ventricle pumps blood into the pulmonary trunk which takes the blood to the lungs. This is where carbon dioxide is offloaded and oxygen is loaded onto the hemoglobin. Hemoglobin is located on a red blood cell (erythrocyte).

Valves

Blood flows from the atria to the ventricles in one specific direction which is made possible by the four valves within the heart. These valves open and close in response to different pressures on either side.[3] The AV or atrioventricular valve is located where the atria meet the ventricle. The right AV valve is known as the tricuspid valve. The AV valve has three flaps of endocardium and connective tissue to give it rigidity. The left AV valve has two cusps and is also referred to as the bicuspid or mitral valve.

Attached to the flaps of the AV valves are the chordae tendineae. These are also known as the heart strings. These strings anchor the cusps and connect to the papillary muscle, which consists of two bands of muscle that protrude from the ventricle wall.



The aortic and pulmonary valves, also known as the semilunar valves, are located at the base of the aorta and pulmonary trunk and prevent backflow.[3] Each valve has three cusps and is shaped like a half moon. Like the AV valves, the semilunar valves open and close in response to intraventricular pressure.

Because of the way blood flows through the heart, the right ventricle only pumps blood to the lungs for oxygenation. Since the lungs are near the right side of the heart, the muscle wall of the right ventricle is thinner than that of the left ventricle.

The left ventricle has a very thick wall to sustain high pressures. This is because the left ventricle must pump the blood through the mitral valve into the aorta, ultimately dispersing the blood to the entire body.

Nodes

The heart is equipped to depolarize and contract even when outside the body. Nerve fibers innervate the heart to alter its rhythm based on oxygen needs.[3] Heart rhythm can also be altered when the autonomic nervous system elicits its fight or flight response.

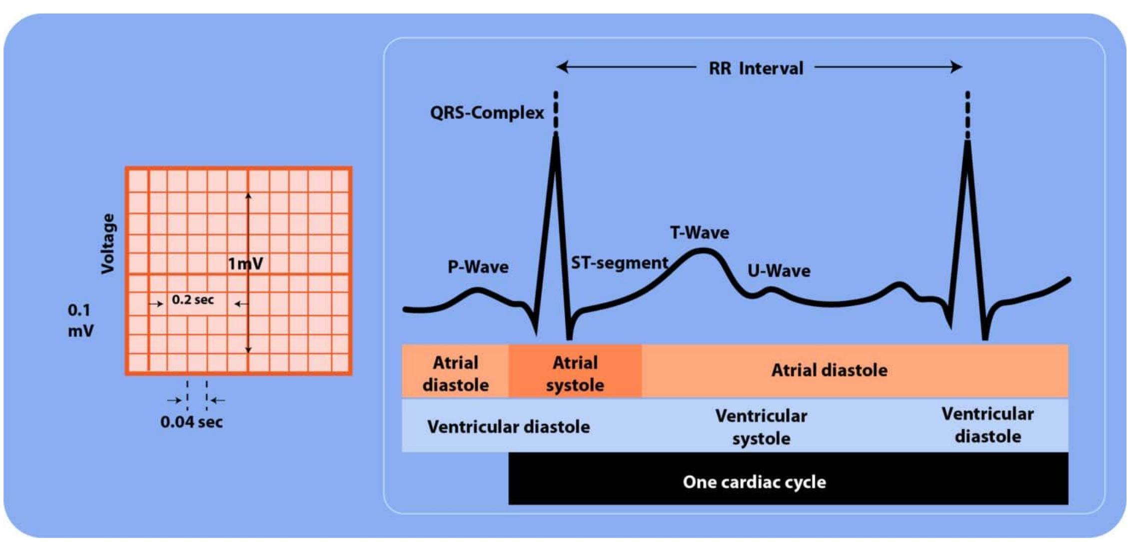
Specific cells within the heart called cardiac pacemaker cells can depolarize using potassium and sodium ions (K+ and Na+). The Sinoatrial (SA) node is also known as the pacemaker. The SA node generates impulses that are sent to the AV node.

The atrioventricular node or AV node then receives the signal about 0.1 seconds later. This delay is critical in heart contraction because it allows the atria to contract and then enables the ventricles to contract. After the signal is received at the AV node, it then goes to the AV bundle. This branches out into the myocardium. The signal then travels into the subendocardial network which depolarizes the cells and gets them ready for a contraction.

Electrocardiogram (ECG)

An electrocardiogram (ECG) is a graphic representation of heart activity. An ECG shows the action potential that is generated by nodes.[3] It does not show the physical actions that are happening in the heart. An ECG appears visually as lines on a graph that go up and down. There are three waves that are very distinguishable in a normal ECG. The first wave is the P wave.

This typically happens when the atria depolarize. After that there is the QRS complex. This is typically the large, tall section of the line. This is what happens on an ECG when the ventricle depolarizes and then proceeds to contract. The last part of the wave is the T wave. This is when the ventricle repolarizes.



Cardiac Output

Cardiac output or CO is the amount of blood pumped out of the heart in one minute. To find out what the volume per minute (CO) is take the total volume per stroke, and the stroke volume, and multiply it by the heart rate.

The formula is as follows: CO = HR X SV.

Cardiac output is dependent on heart rate and stroke volume. If one variable is manipulated, then cardiac output will change. Cardiac reserve is the difference between cardiac output maximally and at rest.[3]

Stroke volume is found by taking the end diastolic volume and subtracting the end systolic volume. Diastolic volume is the amount of blood left in the heart in a resting state. Systolic volume is the amount of blood left in the ventricle after it has contracted.

The contraction phase happens when blood is ejected and is known as systole. The relaxation phase, where the chambers refill with blood, is called diastole. It should be noted that there's a small amount of blood left in the ventricles after the heart has contracted called end-systolic volume.

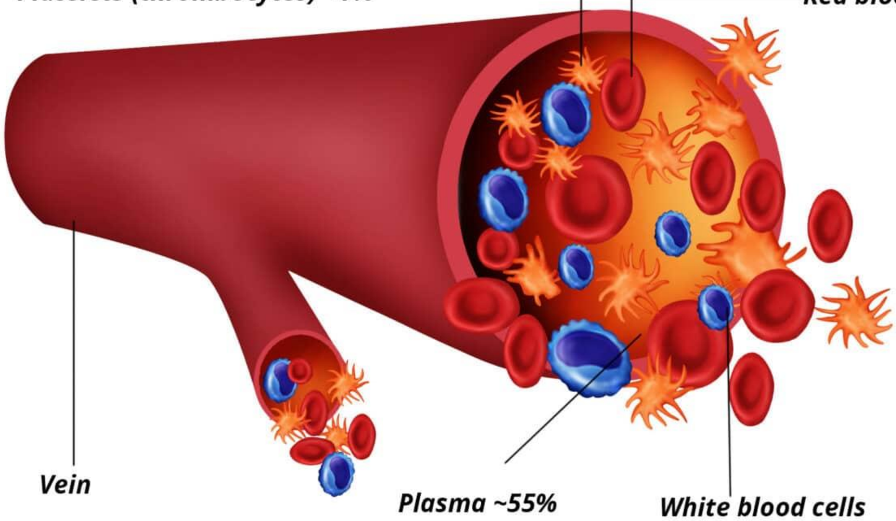
Blood

Blood is the bodily fluid that runs through the cardiovascular system and delivers nutrients and removes waste, among other functions.

Blood is composed of three main parts: plasma, red blood cells, and platelets.[3]

Plasma is a fluid that consists primarily of water with proteins, mineral salts, fats, sugars, hormones, and vitamins dissolved or contained in it as well. Plasma transports the other components of blood, which make up around 55 percent of blood volume.

Red blood cells, or erythrocytes, make up 44 percent of total blood volume and are the densest component in blood. White blood cells (leucocytes) and platelets (thrombocytes) make up most of the final 1-2 percent of blood volume.



Blood has many functions in our bodies including:

- Transporting oxygen and nutrients for uptake in cells
- Removing metabolic waste for excretion
- Regulating body temperature
- Preventing further blood loss via clotting
- Preventing infection via antibodies and cells carried in blood

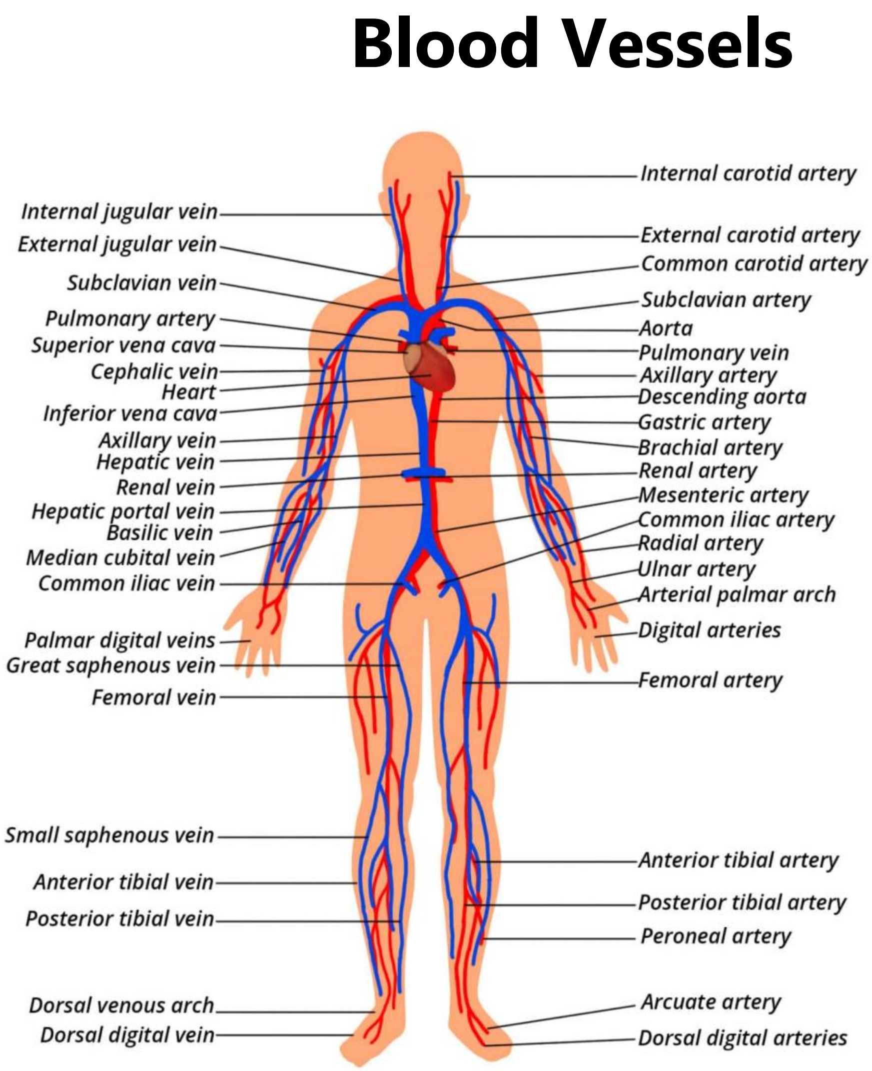
Red blood cells are also called erythrocytes. These are microscopic discs that use hemoglobin to transport O2 and CO2. Red blood cells are made within red bone marrow that is stimulated by the kidney.

Finally, there are white blood cells, which are the body's defense against bacteria. These cells increase during bacterial infections. White blood cells are also attracted to inflammation.

The following are a few of the major specific functions of blood:

1. Blood delivers oxygen and nutrients from both the lungs and digestive track.
2. The blood oversees transporting metabolic waste products from cells to the lungs or kidneys which will then be excreted as urine.
3. Blood helps maintain homeostasis by maintaining body temperature. This occurs as blood brings heat from inside the body towards the skin for better dissipation into the environment.
4. Blood transports hormones from organs to the target destination.
5. Blood helps maintain normal pH levels in body tissue by providing buffers to keep things from getting too acidic.
6. Blood helps prevent blood loss from wounds by initiating clot formation.

7. Blood helps prevent infection by delivering antibodies and white blood cells to infected tissue.



8.

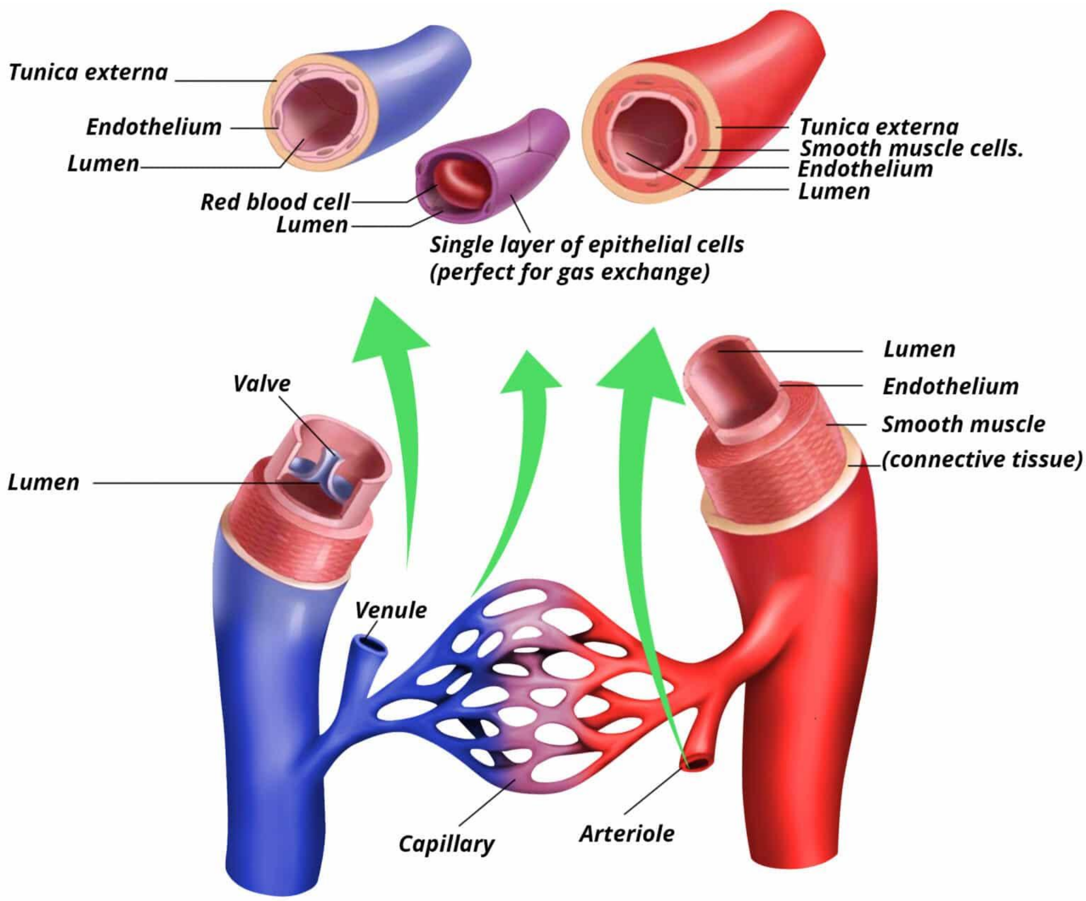
There are three major types of blood vessels:

- Arteries
- Capillaries
- Veins

As the heart contracts, it pumps blood into large arteries that leave the ventricles of the heart.[3] After the blood leaves the main arteries, it is pumped into smaller arteries, which are called arterioles. Arterioles then feed into the capillary beds, which are found in the organs and tissues.

Once the oxygen and carbon dioxide exchange takes place, the blood travels to the venules. Venules are considered the smallest veins. As the blood travels toward the heart, it merges into larger and larger veins. Once the deoxygenated blood meets the heart, it enters the atrium.

Every artery and vein consist of a tunica intima, which is the inner layer of the vessel, tunica media (found in the middle), and tunica externa (the outermost layer).



One major structural difference between veins and arteries is that veins contain valves to prevent the backflow of blood into the tissue and encourage blood to travel toward the heart. Arteries do not need valves because the pressure from the heart contraction pushing the blood towards the organs and tissues prevents any backblow.

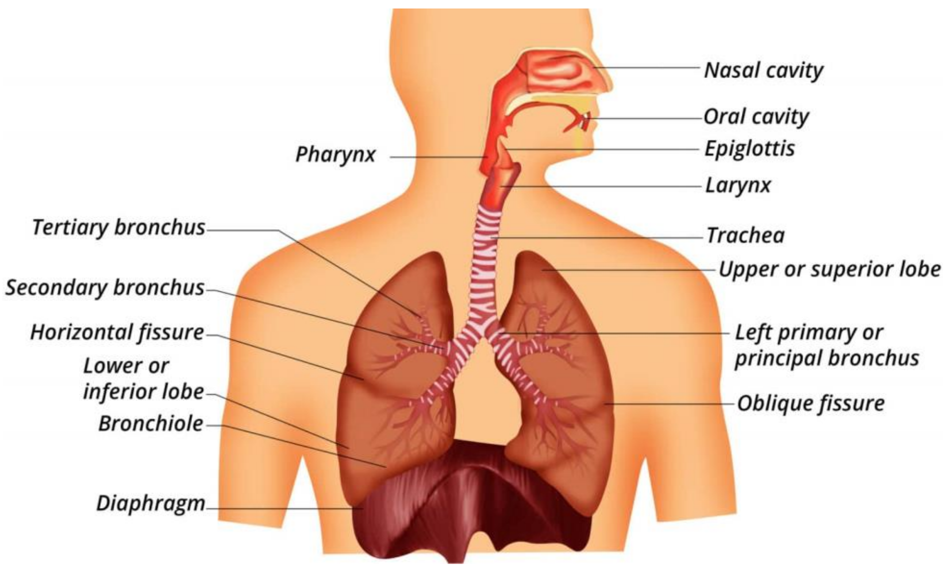
Healthy arteries can handle the intense pressure of blood being pumped from the heart. Arteries can develop issues because of lifestyle factors and genetics, which results in plaque buildup and hardened arteries. Also known as atherosclerosis, the hardening of the arteries poses serious health risks, including stroke and death.

Some common causes of the start of atherosclerosis include blood-borne chemicals, hypertension, bacterial infections, and smoking. Once the arterial wall is damaged, it forms a fatty streak, which then turns into a fibrous plaque and then the plaque can become unstable. Once the plaque becomes unstable it may rupture.

Atherosclerosis is especially problematic for someone with hypertension. The hypertensive pressure beats on the plaque and can cause it to come loose from the wall. This commonly results in the formation of a blood clot. Atherosclerosis accounts for about half the deaths in the developed world.

Lungs & Respiratory Pump Structures

The respiratory system consists of the airways, lungs, and respiratory muscles and provides oxygen to the body while expelling carbon dioxide. The respiratory system has four major functions: providing pulmonary ventilation, external respiration, transport of respiratory gasses, and internal respiration.[3]



Pulmonary ventilation (breathing) is the process of air moving in and out of the lungs. Air is first drawn through the nostril down through the nasal cavity, then it travels to the pharynx. The pharynx leads into the trachea, then the carina of trachea, which splits the airway and leads air to the left and right bronchi.

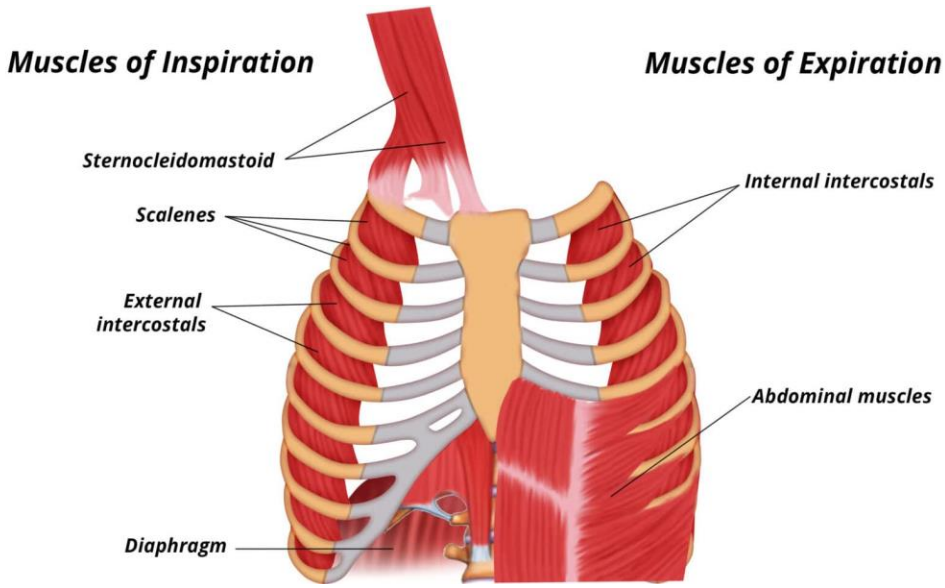
External respiration is the process of oxygen diffusing into the blood and carbon dioxide diffusing into the lungs. Once oxygen diffuses into the blood, the cardiovascular system takes over to transport the oxygen to the specific tissue where it is needed.

Lastly, internal respiration happens when oxygen diffuses from the blood to the tissue and carbon dioxide diffuses from the tissue to the blood. The main anatomical structures that are part of the respiratory system include the nose, the nasal cavity, the paranasal sinuses, the pharynx, larynx, trachea, bronchi, and the alveoli.

The respiratory system is split into an upper and lower section. The lower respiratory system starts at the larynx and ends at the alveoli. The alveolar sac is where the capillaries line the sac to get blood as close to the air as possible. The alveoli are the location in the human body where gas exchange from the blood to the air takes place.

Muscles of Respiration

The diaphragm is one of the main muscles used in inspiration. The diaphragm has a natural cone shape. Inspiratory muscles called intercostals are located between the ribs which help lift the rib cage and lower the rib cage during expiration.



During inspiration, the diaphragm is drawn downward, and the rib cage is drawn upward. As the thoracic cavity volume increases, the pressure inside the lungs decreases. Air then flows into the lungs because of the pressure gradient.

When someone breathes out, the inspiratory muscles lower the rib cage by relaxing, and the diaphragm moves inferiorly. This reduces the lung cavity volume which then raises the inside lung pressure, forcing the air out of the lungs, through the respiratory tract, and into the environment.

Cardiorespiratory System Function

To initiate the entire process of delivering oxygen to the body, the diaphragm contracts and moves downward. The extra space created by the diaphragm contraction also increases the lung capacity.

This increase in capacity decreases the pleural pressure in the lung. Because air moves from high pressure to low pressure, air from the environment moves into the lungs. Air then passes through the nostril, enters the nasal cavity, and gets passed down the pharynx, through the larynx and then into the trachea. Once through the trachea, the air is passed into the right and left lungs by the bronchi and bronchioles.

The air ultimately ends up in the alveoli, which are terminal branches of the lung with thin membranes separating the air from blood in the capillary bed of the lungs. The alveoli are grouped into alveolar sacs, and capillaries wrap around each alveolus.

Oxygen from the air then diffuses across the membrane and into the blood, while carbon dioxide diffuses into the lungs to be exhaled.

Air passes into the bronchioles, which end in a terminal bronchial and a respiratory bronchial. Air passes into the alveolar duct, which fills the alveoli. A group of alveoli is called an alveolar sac. This is where the capillaries are wrapped around each alveolus.

The oxygen has been extracted from the air and diffuses across the membrane onto a red blood cell. Once the red blood cell leaves the capillary beds of the lungs, it travels through pulmonary veins which then leads into the left atrium.

Note that pulmonary veins contain oxygenated blood which flows into the left atrium, unlike normal veins which take deoxygenated blood from the body into the right atrium.

Once in the left atrium, the blood travels through the mitral (bicuspid) valve. It flows to the left ventricle and then when the heart contracts the blood is pushed through the aortic valve which leads to the aorta.

The aorta and other supporting arteries are considered elastic arteries or conducting arteries. The elastic arteries then flow into muscular arteries or distributing arteries. Once in the muscular arteries, the blood then flows into the arterioles.

Arterioles are the smallest artery branch. The blood moves through the arterioles into the capillaries, which are arranged in capillary beds.

Capillaries are very thin and in some cases one endothelial cell makes up the circumference of the capillary wall. This is where the red blood cell delivers its oxygen because of the oxygen gradient across the cell membrane.

Red blood cells have a natural affinity for carbon dioxide, which gets loaded onto the red blood cell to replace the oxygen, with some carbon dioxide dissolving directly into the blood. The blood then carries red blood cells heads from the capillaries to the venules when leaving the tissue. Venules form veins that get larger as they get closer to the heart. Veins do not have as much smooth muscle as arteries therefore veins rely more on pressure gradient.[1]

Once the deoxygenated blood reaches the heart it enters through the superior vena cava or the inferior vena cava. The superior vena cava collects all the deoxygenated blood from the upper body. The inferior vena cava collects all the deoxygenated blood from the lower half of the body.

The blood flows into the right atrium and then through the tricuspid valve which brings the blood into the right ventricle. Once the blood is in the right ventricle it is then pumped through the pulmonary valve which then enters the left pulmonary artery and the right pulmonary artery. The pulmonary arteries head back to the lungs where carbon dioxide is exchanged with oxygen via the alveoli to start the cycle again.

Cardiorespiratory System Responses to Exercise

As stated above the SA node and AV node can initiate the electrical impulse and thereby cause the heart to beat. All of this keeps the heart beating at a consistent rate. The sympathetic and parasympathetic nervous system as well as a few hormones can speed up or slow down the heart rate.[1]

The sympathetic nervous system stimulates the release of catecholamines: epinephrine and norepinephrine. These act to increase SA node activity which will increase heart rate.

The parasympathetic nervous system stimulates the vagus nerve which releases acetylcholine. This is a hormone that has a depressing effect on the SA node, which decreases its firing activity. With a decreased firing activity this will decrease the heart rate. A decreased heart rate is known as bradycardia. An increase in heart rate is known as tachycardia.

Typically, high performing athletes have a low resting heart rate. In the clinical sense, when a patient has a low heart rate it can be an indication of some sort of cardiac problem.[1] In a healthy athlete a low resting heart rate can indicate increased levels of efficiency on the heart, nervous system, and lungs.

Acute Responses to Exercise

During acute bouts of exercise oxygen consumption (VO_2) increases to meet the high demands of working muscle and other tissues.[1] As exercise intensity increases there will be a greater demand for energy and therefore a greater demand for oxygen.

As mentioned above, cardiac output is the product of heart rate and stroke volume. To meet the demands of an acute exercise bout, the body must increase cardiac output. During the early stage of exercise, heart rate and stroke volume will increase to increase cardiac output. In this state, most of the circulating blood is diverted from things like digestion to working muscles where it's needed most in that moment.

Chronic Adaptations to Exercise

If an individual stays compliant with an exercise program for a long period of time they may experience long-term adaptations to the cardiorespiratory system. With a prolonged cardiorespiratory exercise program, adaptations include increased stroke volume, higher cardiac output, a decrease in systolic and diastolic blood pressure, and an increase in left ventricular muscle mass.[1]

It should be noted that the respiratory system is not usually a major limiting factor in increasing exercise efficiency. This is because, in general, lung capacity changes very little from exercise. Long term endurance training tends to simulate hypervolemia. This is where the body increases blood volume to help the cardiorespiratory system become more efficient by being able to supply more oxygen. Most of the blood volume increase comes from plasma and very little comes from red blood cells.

Improvements to VO_2 max occur with prolonged aerobic training and reflect improvements in the ability of the heart to pump blood and the ability of the muscles to use the oxygen provided.

Environmental Factors Affecting CRS

Severe environmental conditions can cause the cardiorespiratory system to work harder to meet the body's oxygen demands. Exercising in the heat causes the body to shuttle more blood to the skin to help dissipate body heat.

This is typically shown when someone gets hot, they end up turning a shade of pink or red. As blood flow to the skin is increased, vasculature can become engorged and cause blood pooling.[2] Blood pooling reduces the venous return and can pause the cardiovascular system in order to work harder in filling the heart.

Dehydration caused by extreme heat can result in a decreased amount of plasma volume. This means less blood is available for working muscles and to maintain normal body functions. The body copes with this by increasing the heart rate which may not be enough to maintain cardiac output.

Exercising in a cold environment can cause heat loss during exercise. Long duration of exercise in the cold can increase the risk of hypothermia. This is especially true when core body temperature lowers.

To counteract this, the body tries to create heat by shivering and through the vasoconstriction of blood vessels in the skin. The respiratory rate is usually higher and maximal oxygen consumption may be slightly lower.

Altitude is another factor that can affect the cardiorespiratory system.

When someone increases their elevation the pressure of oxygen becomes reduced.[2] This makes it harder for oxygen to diffuse into the tissue because of the lack of pressure gradient. To compensate for this, breathing rate is usually increased with altitude.

Summary

The cardiorespiratory system contains the pulmonary system and the cardiovascular system. The pulmonary system contains the lungs and airways and is responsible for providing oxygen to the body while expelling carbon dioxide. It also provides ventilation, respiration and exchange of gases.

The cardiovascular system contains the heart, blood vessels, and blood. The heart pumps blood throughout the body, which helps to deliver nutrients and oxygen and to remove waste alongside many other functions.

During exercise the consumption of oxygen increases to meet the energy needs of the body and cardiac output goes up. Regular cardiovascular training will increase VO_2 max, because of improved performance in cardiorespiratory efficiency.

Fitness professional should also be aware that environmental factors can impact the cardiorespiratory system, like dehydration and altitude, and prepare accordingly with monitoring fluid intakes or modulating exercise intensity to ensure sessions are safe and productive.

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Chapter 5

The Endocrine System

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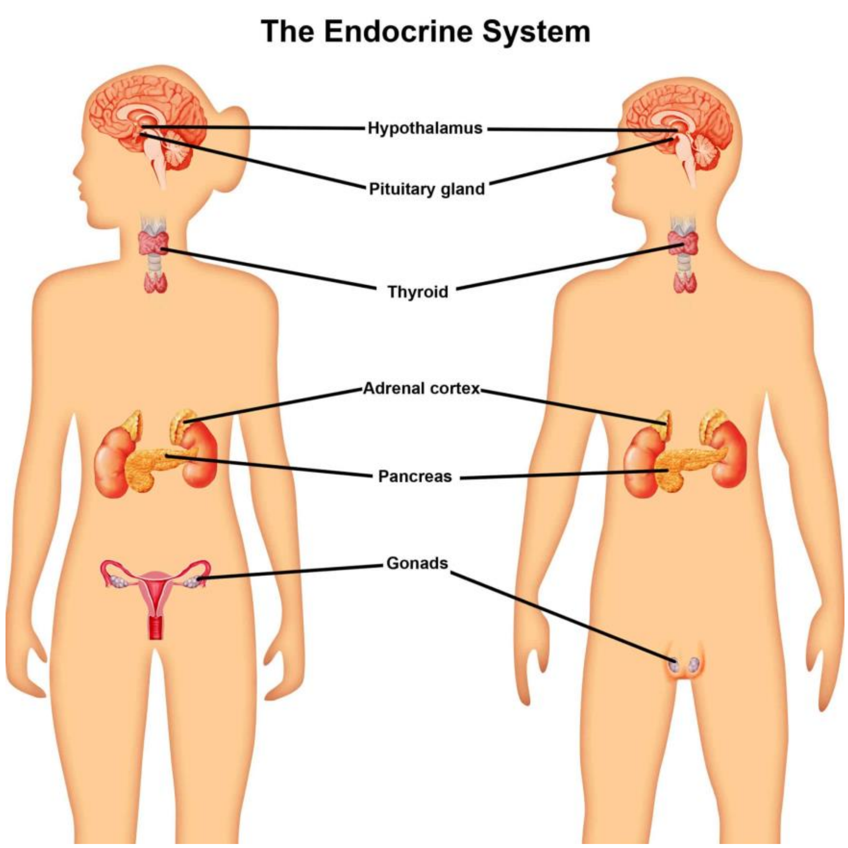
Introduction to the Endocrine System

The endocrine system plays a key role in exercise in both acute responses and long-term adaptations. This system consists of hormones, the glands that produce them, and the receptors in the body that respond to hormones. Fitness professionals must have a basic knowledge of the endocrine system given its importance to exercise science for properly understanding the adaptations that occur in the body in response to exercise.

The endocrine system is a three-part system composed of endocrine glands, hormones, and receptors. Glands are scattered throughout the body and in specialized brain areas. The cells in these glands carry out functions by secreting specific chemicals called hormones.[1,2]

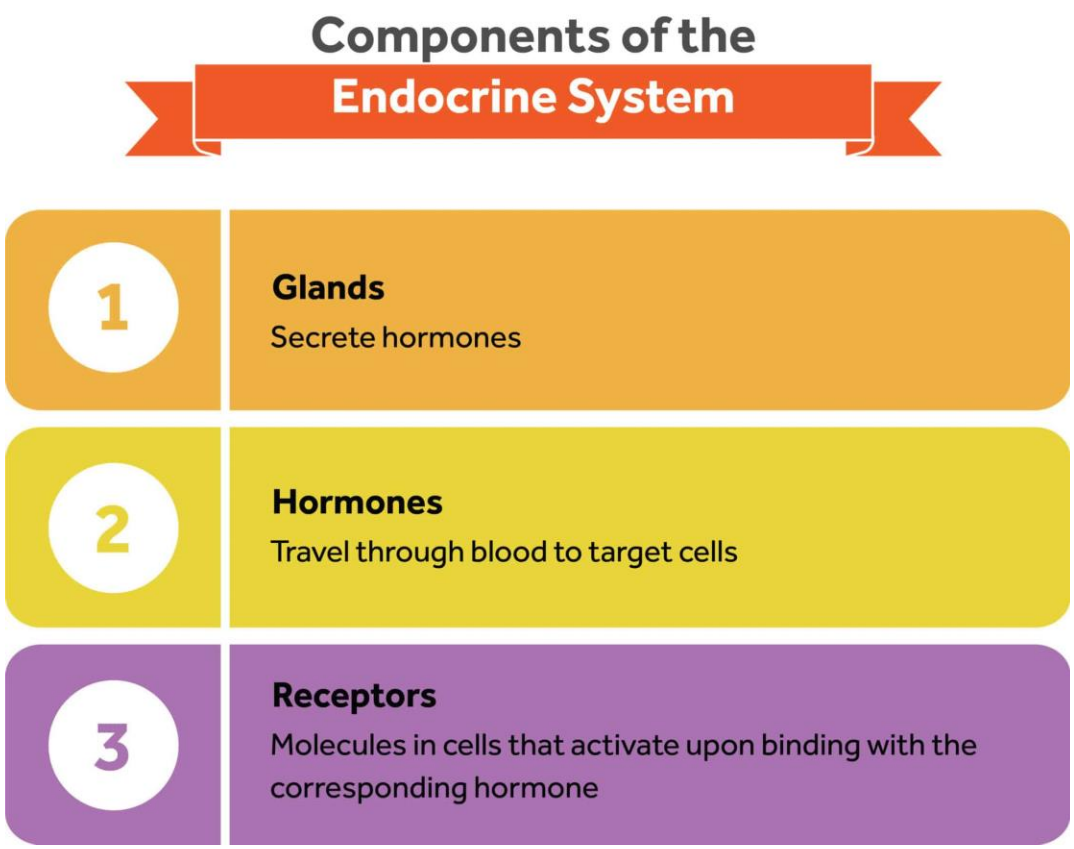
Hormones are chemical messengers released in the blood that causes a change in the target cell when binding to receptors.[1,2] Receptors are docking molecules in the target cell that get activated when a hormone binds to it, triggering a cascade of biochemical reactions that eventually modify the cell's function or activity.[1,2]

For the body to function, it requires interdependent communication and close coordination between all seven systems in the human body. The endocrine system evolved as a mechanism to communicate and regulate signals within the body.



The endocrine system is a complex network of glands, hormones, and receptors that works harmoniously with the nervous system to control and coordinate energy, reproduction, growth, immunity, and behavior.[1] To ensure that a constant internal environment (i.e., homeostasis) is maintained, the nervous system allows rapid transmission of information from the brain to the nerves in the body.[1,2]

Conversely, the endocrine system relies on producing and releasing hormones from various glands and transporting those hormones via the bloodstream.[1,2] Thus, the two communication systems work in tandem to complement each other.



Major Endocrine Glands and Hormones

Most hormones are produced by endocrine glands, termed after the Greek for 'internal secretion.' In response to a stimulus, hormones are released from the gland directly into the bloodstream until they reach the target organ.[2] An example of a classical endocrine gland is the thyroid gland, which functions to synthesize and release thyroid hormones into the bloodstream.[2]

On the contrary, exocrine glands release hormones through a duct or opening to a body surface.[3] Examples of exocrine glands include sweat glands, lacrimal glands, salivary glands, mammary glands, and digestive glands in the stomach, pancreas, and intestines.[3]

The following table shows the major endocrine glands and the hormones they secrete:

Major Endocrine Glands		
Gland	**Hormone**	**Function**
Hypothalamus	Releasing hormones	Stimulate pituitary activity
Pituitary	Thyroid-stimulating hormone (TSH) Growth hormone (GH) Prolactin Vasopressin Oxytocin	Stimulate thyroid, adrenal, gonadal, and pancreatic activity
Thyroid	Thyroid hormones	Regulate metabolism, growth, behavior, and puberty
Adrenal cortex	Cortisol Aldosterone	Regulate metabolism, behavior, and stress
Pancreas	Insulin Glucagon	Regulate blood sugar levels
Gonads	Testosterone (male) Progesterone (female) Estrogen (female)	Regulate growth, reproduction, immunity, the onset of puberty, and behavior

Functions of the Hormones in the Human Body

Hormone Regulation

Maintaining a stable physiological equilibrium (homeostasis) requires tight control of hormone production and regulation. Hormone regulation begins in the hypothalamus, the master switchboard gland that sits at the base of the brain and is about the size of an almond.[2] Below the hypothalamus sits the pituitary gland which responds to the commands of the hypothalamus.[2]

When the endocrine system perceives stimuli, it regulates hormones through a negative feedback loop. When an endocrine gland senses high concentrations of one hormone in the body, it changes to decrease the production of that hormone and bring a stable equilibrium in the system. This three-way communication method begins in the hypothalamus, followed by the pituitary gland until it reaches the target organ.[2]

When the circulating hormones have reached the target cells and levels are sufficiently high, the hypothalamus and pituitary gland cease release, thereby turning off the cascade.[2] In some cases, the sensitivity of the feedback systems alters based on physiological states or stages of life.

For example, in fetal development, the concentration of growth and sex hormones is the highest and culminates in adulthood when the sexual glands have acquired total reproductive capacity.[4] On the contrary, positive hormonal feedback is possible in the case of ovulation in the menstrual cycle.

Behavior Regulation

Hormones play an important role in influencing the nervous system. Over time, they have evolved to influence body systems in paths that elicit the appropriate behavior or social cue. In all mammals, the interacting components of the behavioral system include:

1. Inputs (sensory systems)
2. Integrators (central nervous system)
3. Outputs (tissues and organs)

Because endocrine glands produce hormones that can enter target cells and change gene expression, specific behaviors can occur in the presence of signals, stimuli, and receptor interactions.[2]

For example, estrogens, the female hormones associated with reproduction, growth, and onset of puberty, show similarities with the regulation of female sexual behaviors. Interestingly, the reciprocal relation can occur where behavior affects hormone concentrations. For example, high testosterone concentrations are associated with aggression, while cortisol and serotonin act antagonistically to reduce the effects of testosterone.[5]

As previously discussed, the hypothalamus is the primary center for communication between the nervous and endocrine systems. One way hormones regulate mood and behavior is through the hypothalamus-pituitary-adrenal axis (HPA-axis).[2] For example, HPA axis overstimulation and chronically high cortisol levels are associated with depression, anxiety, mood swings, and irritability.[6]

Another way the brain can regulate emotions is by releasing certain chemicals called neurotransmitters. Neurons release neurotransmitters to communicate between different brain areas and influence human moods, emotions, and behavior.[7] Four main chemicals are associated with behavior regulation, including serotonin, dopamine, adrenaline, and oxytocin.

1. Serotonin is the neurotransmitter responsible for pleasure, happiness, and stability.[7]

2. Dopamine is the neurotransmitter responsible for reward, joy, and happiness.[7]
3. Norepinephrine is the neurotransmitter responsible for fear and anger emotions that trigger a "fight or flight" response.[7]
4. Oxytocin is the neurotransmitter responsible for love and attachment.[8]

Sex-Related Differences

Humans, like most animals and plants, present with one obvious anatomical difference, the existence of two biological sexes. According to biologists, **sex** is the trait that differentiates males or females based on reproductive and sexual organs, chromosomes (XX for female and XY for male), gene expression, hormone levels, and physiological features.[9] Gender refers to the range of socially constructed roles, behaviors, expressions, and identities used to categorize male and female differences.[9]

Reproductive Organs

The reason why two distinct sexes, males, and females, are commonly necessary for life to reproduce is one of the oldest biological enigmas. One prominent theory is that sex evolved to produce variation, an adaptative trait that gives organisms an advantage in changing environments.[10]

The main distinction between males and females is the way DNA is packaged into the sex cells that make new organisms, called gametes.[2] The female sex is capable of producing large gametes (ovules), whereas the male sex produces small gametes (spermatozoa).[2]

Gonads and Sex Hormones

The second characteristic differentiating males and females are the presence of endocrine glands and sex hormones. First, gonads are specialized reproductive glands that produce germ cells.[2] The ovaries are the female gonads that produce ova, and the testes are the male gonads that produce spermatozoa.[2] Second, sex hormones synthesized by gonads play an important role in physiological distinctions between males and females.[2]

While males and females generally have the same hormones (i.e., estrogens, progesterone, and testosterone), their production sites, blood concentrations, and interactions with different organs are different.[11] Males predominantly produce testosterone and lesser amounts of estrogen and progesterone.[2] Female ovaries mainly synthesize estrogen and progesterone and produce lesser amounts of testosterone.[2]

In the last decade, medical advancements have broadened the understanding of the influence gender has on both human physiology and the pathogenesis of diseases. The most common anatomic-physiological difference between male and female athletes is that males commonly present with stronger bones, greater muscle mass and strength, and greater aerobic capacity.

In contrast, females exhibit less muscle fatigue and faster recovery during endurance exercise.[12] Beyond that, conditions such as thyroid disease, diabetes mellitus, osteoporosis, obesity, and sarcopenia show sex-specific patterns in disease prevalence, pathogenesis, outcomes, adverse events, and responses to medical treatment.[13] Thus, when working with individuals with medical conditions, it is crucial to tailor exercises considering sex and gender in every disease element, from the causes to the treatment.

Hormones and Exercise

Several environmental stressors affect an organism's biology and endocrine system. Engaging in strenuous forms of exercise and training for sports competitions are examples of situations that trigger a stress response in the body and impact hormone homeostasis. This section will focus on understanding the role testosterone, estrogen, GH, insulin, glucagon, catecholamines, cortisol, and thyroid hormones play in response to exercise.

Testosterone

Testosterone (T) is the main androgenic steroid hormone, abundantly produced in the testes and in lesser amounts in the ovaries and adrenal cortex.[2] As an androgen, its primary role is to stimulate the development of male characteristics.[2] The specific functions of testosterone vary during different developmental stages.

For example, during fetal development, testosterone is most elevated to support the growth of male genitalia.[2,14] Until then, males and females have similar amounts of testosterone production.

However, during puberty, there is an approximately 30-fold increase in testosterone production in males, resulting in changes in mood and behavior, and anatomical traits such as height, deepening of the voice, growth of facial, pubic, axillary, and body hair; and increase in muscularity and strength.[2, 15]

As a result of this higher testosterone production, boys gain considerably more lean body mass than girls.[16] In adult life, testosterone maintains libido and regulates sperm production.[2]

In addition, testosterone plays an essential role in regulating muscle protein synthesis and muscle hypertrophy. New research suggests that chronic increases in testosterone levels can significantly increase hypertrophy and strength, whereas decreases in basal testosterone levels result in the opposite effect.[17]

For both sexes, the typical pattern of testosterone release commonly follows a diurnal rhythm, with peak concentrations in the morning and a progressive decline over the day.[18] In women, testosterone concentrations can also fluctuate as a function of the menstrual cycle.[19]

Estrogen

Estrogen (E) is a steroid hormone that virtually exists in the body as estradiol and is associated with the female reproductive organs.[2] In females, estrogen is mainly produced in ovarian androgens, whereas in males, testes produce only 20% of circulating estrogens, with the rest deriving from peripheral organs like adipose, brain, skin, and bone, which convert testosterone to estrogen.[20]

The main function of estrogen is to coordinate the normal development and functioning of the female genitalia and breasts.[2] Serum estrogen concentrations are highest during female pregnancy than during the rest of the female life cycle. In practice, estrogen is a reliable indicator for assessing fetus injury and early prevention of chronic placental insufficiency.[21]

During puberty, estrogen concentrations increase to stimulate the growth of the uterus, breast, and vagina; coordinate fat deposition and distribution in the body; regulate the pubertal growth spurt and cessation of growth at adult height, and control the development of secondary sexual characteristics.[2] In adult women, estrogen controls the menstrual cycle, pregnancy, and lactation and maintains female libido.[2]

Later in life, the ovaries will stop producing estrogen (i.e., menopause) and are accompanied by symptoms such as changes in monthly cycles, hot flashes, sweating, heart palpitation, increased irritability, anxiety, depression, and brittle bones (i.e., osteoporosis).[2]

While the effects of aging on women are associated with several negative outcomes, including a decline in sex hormone production, an increase in injuries, and muscle wasting, estrogen is known to have a protective effect on musculoskeletal function.

There is evidence to suggest that estrogen stimulates muscle repair and the regenerative processes by improving the structure and function of musculoskeletal tissues like muscles, tendons, and ligaments, increasing muscle mass, strength, and collagen content.[22]

In turn, these effects influence muscle contractile properties and aid in post-exercise muscle damage.22 During exercise women generally exhibit a greater increase in serum concentrations of estrogen than males.23

As a result, female athletes that permanently show low levels of female sex hormones, accompanied by menstrual cycle perturbations, are more prone to stress fractures and ligament injuries.[24,25,26]

Growth Hormone

Growth Hormone (GH) is the most abundant hormone produced by the pituitary gland.[2] As the name implies, GH regulates the growth and development of reproductive organs, adipose tissue, connective tissue, endocrine glands, muscle, and bones.[2]

The specific functions of growth hormones vary during different life stages of development. GH levels peak in early childhood to support tissue growth and decline afterward.[2]

Nevertheless, GH production in adult life is still important as its commonly associated with symptoms of aging.2 In addition, GH gets released by stress, low blood sugar levels (i.e., hypoglycemia), strenuous exercise, and deep sleep.

Ultimately, GH plays an important role in macronutrient metabolism as seen below:

- Glucose: GH lowers uptake by muscle cells, raising glucose levels in the blood and promoting glucose production from non-glucose molecules (i.e., gluconeogenesis) in the liver.[2]
- Amino acids: GH enhances the uptake of amino acids from the blood into cells and incorporates them into proteins.[2]
- Fat: GH stimulates the breakdown of lipids (i.e., lipolysis) and lipid oxidation in adipose tissue, suppresses glucose uptake, and consequently increases plasma glucose.[2,23]

GH is involved in development and maturation and is associated with skeletal muscle growth and function. Some research findings suggest that the anabolic action of GH is mediated by circulating insulin-like growth factor 1 (IGF-1) that comes from the liver and inhibits protein breakdown.[27]

Another way is by enhancing muscular and extra-muscular sites and increasing muscle mass without affecting contraction or muscle fiber composition.[27] However, the literature on growth hormones contributing to tissue growth and strength remains controversial.

Additionally, there is a lack of consensus regarding sex-related differences in growth hormone response to exercise. So far, most research studies report similar results between both sexes in which men and women experience an increase in growth hormone levels in response to exercise.[27]

The only difference has been seen in the duration of GH release.[23] For example, females experience GH peaks sooner than males, whereas men sustain longer responses.[23] The attributable factors to this response are the lack of testosterone in women and the compensatory mechanism of having higher concentrations of resting basal level of GH and estradiol.[23] Ultimately, the sex differences in growth hormone response to exercise immediately impact blood glucose control.[23]

Insulin

Insulin is one of the main hormones produced in the pancreas and the only blood-lowering hormone in the body.[2] It is in the beta cell of the Islets of Langerhan and is released to lower blood glucose levels after ingestion. Insulin plays an important role in all storage forms of energy and works on target organs specializing in energy storage, such as the liver, muscles, and adipose tissue as described below:

- Glucose: Insulin stimulates glucose uptake into cells, glucose breakdown, and inhibits gluconeogenesis.[2]
- Protein: Insulin promotes amino acid transport and protein synthesis in muscle cells, and inhibits gluconeogenesis in the muscles.[2]
- Fat: insulin increases fat synthesis in the liver and adipose tissue, and inhibits glycerol breakdown which also can serve as a starting material for gluconeogenesis.[2]

Insulin release is regulated by various factors including eating patterns, and hormones such as GH, glucocorticoids, and thyroid hormones.[2] The influence of exercise on insulin has long been studied as an example of favorable adaptive change from two opposing metabolic regulatory forces. While insulin is an anabolic hormone that is secreted to increase glucose and fat storage after eating, exercise is a condition that suppresses and oxidizes the fuel storage effects of insulin.[28]

During exercise, serum insulin concentrations decrease by inhibiting the release of insulin from the pancreas.[28] In turn, glucose uptake from glycogen reserves stored in muscles and the liver increases and produces ATP to fuel contracting muscles.[29] As a result, blood sugar levels decrease up to 24 hours or more after a workout resulting in higher sensitivity to insulin.[30]

As an anabolic hormone, insulin stimulates the cellular pathway that regulates muscle growth. For example, patients with uncontrolled diabetes and type 2 diabetes are known to have a relative deficiency of muscle mass and quality, presumably due to insulin resistance.[31] In one study, insulin administration in diabetic patients induced the expression of two muscle growth factors: MyoD, and myogenin.[32] However, most studies showing positive associations are only seen in animal studies, and whether it directly stimulates muscle protein synthesis in humans remains unclear. [28]

Insulin response to exercise is also highly sensitive to sex differences. Males preferentially use glucose as primary fuel during exercise, whereas females use fat as the major energy source.[31] One suspected explanation for this theory is that women are more efficient at conserving energy and storing fat, based on body fat mass and other anatomical characteristics.[33]

Ultimately, engaging in physical activity stabilizes blood glucose levels during and after the training session, supporting the evidence that exercise improves insulin resistance in individuals with Type 2 diabetes.

Glucagon

Glucagon is the second most prominent blood glucose-regulating hormone in the body. Produced in the alpha cells of the Islets of Langerhans in the pancreas, glucagon works to counterbalance the actions of insulin.[2] Its main role is to raise blood glucose levels during fasting, exercise, and hypoglycemia conditions and oppose the effects of insulin mainly in the liver as shown below:

- Glucose: Glucagon promotes glycogen breakdown and formation of glucose from non-glucogenic sources through the gluconeogenesis pathway in the liver.[2]
- Protein: Glucagon increases amino acid catabolism in the liver, uptake of amino acids by skeletal muscle, and increased excretion of free amino acids.[2]
- Fat: Glucagon stimulates the fat breakdown of triglycerides into fatty acids and glycerides for energy utilization which also can serve as a starting material for gluconeogenesis.[2]

As a catabolic hormone, glucagon's role is to suppress skeletal muscle protein synthesis, irrespective of sex differences. During exercise, glucagon stimulates the liver to break down glycogen. Then, new glucose production from non-glucogenic precursors increases blood glucose, leading to hyperglycemia.[34]

However, arterial glucagon during exercise is incrementally delayed and dampened compared to the increase in glucose released from the liver.[34] Depending on the duration and intensity of exercise, arterial glucagon may not increase.[34] As energy demands from the muscle increase, glucose is released from the muscle in a glucagon-dependent manner.[34]

Catecholamines

Catecholamines are physiologically active compounds that act both as neurotransmitters and hormones.[35] The adrenal glands are responsible for releasing dopamine, norepinephrine, and epinephrine (adrenaline) in response to physical or emotional stress. This is also known as the body's "fight-or-flight" response.[35]

The significance of circulating catecholamines and their possible roles at birth is used to support neonatal adaptation.[36] During early development and birth, plasma catecholamine concentrations are remarkably higher than those in adult life, primarily to maintain glucose supply to the heart and brain and to prepare the lung for ventilation.[36]

Regarding sex differences in catecholamine levels, young females exhibit a lower adreno-sympathetic maturity than males. However, both sexes reach full maturity of the adrenergic sites near the fifth year of age.[37] In adult life, women tend to secrete and clear epinephrine out of the body at lower levels than men. Nevertheless, this change is not dependent on adrenergic maturity but rather is from the increased rate of catecholamine removal.[37]

Exercise increases catecholamine concentrations in athletes, specifically adrenaline and noradrenaline in a sex-dependent manner.[38] One study found that men's epinephrine and norepinephrine levels were higher throughout the training period than those of women.[38]

This occurs by stimulating hepatic glycogenolysis and gluconeogenesis, increasing blood glucose levels during activity, and potentially decreasing glucose levels post-exercise when glycogen stores are being replenished.[23]

Therefore, the catecholamine spike seen in men who exercise could have resulted in a higher mobilization and utilization of muscle glycogen. Ultimately, studies on women remain scarce and the effects of exercise on catecholamine response remain to be specified.

Cortisol

Cortisol, also known as the stress hormone, is a steroid hormone synthesized from cholesterol by the adrenal cortex and regulated by the hypothalamus-pituitary-adrenal (HPA) axis.[39]

As one of the principal glucocorticoids released from the adrenals, cortisol has many functions in the body and can affect nearly every organ system. The primary functions of cortisol include mediating the stress response, regulating carbohydrate, protein, and lipid metabolism, inflammatory response, and immune function.[39]

Cortisol is a hormone secreted to regulate the 24-hour cycles of the body's internal clock, also known as **circadian rhythms**.[40] The secretion is lowest during the early night, increases several hours before awakening, and peaks in the morning within 30–45 min after awakening.[40] In addition, the cortisol awakening response (CAR) is a separate process that works in harmony with the body's circadian rhythms, and it's associated with the anticipation of stressors for the upcoming day.[40]

Like other endocrine hormones, cortisol levels play a role in the stages of growth and development. During pregnancy, maternal cortisol levels increase by two to four times to support neural development and fetal growth.[41,42] Throughout puberty and adolescence, cortisol concentrations increase significantly to function as a synchronizer for the entire circadian system.[43] Additionally, cortisol production stabilizes between ages 20 to 60 and progressively increases after 60 years.[44]

Cortisol is released during a “fight or flight” response to optimize bodily functions and improve alertness in physically or psychologically demanding events. First, it mobilizes energy by releasing glucose from its storage sites and raising blood glucose levels.[39] Second, glucose uptake decreases in the muscle and adipose tissue and increases glycogenesis and gluconeogenesis in the liver. This effect results in muscle growth inhibition.[39] In adipose tissues, cortisol increases lipolysis. Lipolysis is a catabolic process that releases glycerol and free fatty acids.[40] Lastly, cortisol facilitates the pancreas to decrease insulin and increase glucagon and enhances the activity of epinephrine, and other catecholamines.[39]

It’s theorized that repeated exercise can habituate or sensitize the physiologic stress system or HPA axis.[45] While most studies show that exercise intensity correlates with cortisol release above resting levels, high cortisol levels can inhibit protein synthesis resulting in skeletal muscle protein breakdown.[46]

However, serum cortisol levels decrease shortly after exercise and suppress cortisol release at night, subsequently diminishing cortisol responses to psychosocial stressors.[45] Ultimately, continuously engaging in physical activity mediates the stress response and endorphin release resulting in feelings of relaxation and mood improvement.

Thyroid Hormone

The thyroid hormone is composed of two structurally related hormones produced by the thyroid gland: thyroxine (T4) and triiodothyronine (T3). Thyroid hormones increase the metabolism of almost all body tissues.[2]

This includes heat regulation, energy metabolism, growth and maturation, and development of the central nervous system, tissues, and bones.[2] Ultimately, the thyroid gland is virtually responsible for maintaining and regulating all body systems required for life, including the nervous, cardiovascular, and gastrointestinal systems.

As the regulator of several systems, the thyroid hormone significantly contributes to the body’s energy metabolism in skeletal muscle functioning. First, thyroid hormones increase the basal metabolic rate and favor metabolic reactions such as lipid and carbohydrate breakdown and anabolism of proteins.[2]

Second, thyroid hormones regulate changes in the demand and synthesis of ATP in the skeletal muscle.[47] Third, thyroid hormones act on several gene targets that result in the expression of genes responsible for fast-twitch fibers, muscle development, homeostasis, and regeneration.[47] Finally, thyroid hormone availability influences contractile and relaxation reflexes of the skeletal muscle.[47]

The influence of exercise on thyroid function increases the release of thyrotropin-releasing hormone (TRH) that stimulates the secretion of TSH in the pituitary gland. While basal metabolic rate increases with exercise and provides several benefits in different body systems, strenuous exercise may be associated with transient alterations in thyroid hormones.[48]

For example, an underactive thyroid (hypothyroidism) reduces cardiopulmonary function, fatigue, muscle stiffness, and exercise intolerance.[47] In contrast, hyperthyroidism caused by increased thyroid gland function manifests as weight loss, heat intolerance, diarrhea, fine tremor, and muscle weakness.[47]

Interestingly, thyroid diseases affect individuals in a sex-dependent manner, with a prevalence approximately ten times higher in women than men.[49] For athletes, these symptoms can negatively impact their ability to effectively train, compete, and recover. For example, a side effect of overtraining in female athletes is secondary amenorrhea which can lead to thyroid dysfunction.[49]

In addition, athletes with low growth hormone, cortisol, and thyroid-stimulating hormone levels are at risk for diminished tissue growth, repair, and other neuromuscular disorders.[47] Nevertheless, consistency in training is not associated with thyroid function improvement among individuals with thyroid disorders.

While there is a decrease in serum concentrations of TSH, T3, and T4 in periods of increased physical activity, these changes are minor and have the potential for physiologic adaptation.[48]

Therefore, individuals with thyroid alterations should seek advice and pharmacological treatment from a medical professional and pursue exercise training as a lifestyle modification rather than treatment.

Acute and Chronic Adaptations to Exercise

As previously seen, hormonal adaptations naturally result from engaging in physical activity. This section will examine the acute and chronic responses of the endocrine system from various forms of exercise, taking a closer look at the effects of modality, duration, and intensity of a training session.

Testosterone

Testosterone concentrations are positively associated with exercise modality and duration. Total testosterone concentrations acutely increase in most men and young women during a training session, while no changes appear in middle-aged and elderly women.[50]

While this mobilization of testosterone is brief, the effects of testosterone can last from 15 minutes to several hours and support favorable adaptive responses to muscle gain.[17] Interestingly, the acute elevation is higher in resistance-trained men than in endurance-trained men.[50]

Additionally, one study assessing weight distribution found that testosterone and muscle strength are higher if lower-body exercises are performed before upper-body training.[51] Ultimately, moderate-load, high-volume training with short rest periods produces a more significant testosterone response than high-load, low-volume training with long rest periods.[51]

Chronic testosterone changes during and post-resistance training have been inconsistent in the literature on both men and women. While some studies have demonstrated a chronic increase in basal testosterone, others have failed to find an adaptation to regular resistance exercise.[50]

For example, significant elevations have been reported in pubertal boys, whereas no difference exists in resting concentrations between untrained and elite athlete females.[50]

On the contrary, most reports show that resting concentrations of testosterone decrease when there are reductions in volume and intensity of the training period, leading to the speculation that perhaps higher volumes are needed to alter resting levels of testosterone.[50] Ultimately, chronic adaptations from resistance training are associated with increases in lean mass and strength.

Growth Hormone

Growth Hormone acutely increases after resistance training in both men and women. Particularly, concentrations are elevated through 30 minutes post-exercise in both sexes, although the resting concentrations of GH are higher in women.[52]

Additionally, programs of moderate to high intensity, high volume, and short intervals are most successful with the responses compared to conventional programs using high loads, low repetitions, and long intervals.[50]

Chronic concentrations of GH are not affected by traditional resistance training programs as seen in both men and women.[50] This data is also supported by research demonstrating similar concentrations in elite Olympic athletes and strength athletes compared with non-trained individuals.[50]

Insulin

Insulin is affected by blood glucose concentrations and dietary intake. Not taking protein or carbohydrate supplementation before, during, or post-acute resistance training show a significant decrease in insulin.[50] During aerobic exercise, insulin levels decrease and counter-regulatory hormones (i.e., glucagon, cortisol, growth hormone, norepinephrine) increase to keep blood glucose levels steady.[53]

Whereas in anaerobic exercise, insulin levels do not fall as much as during aerobic exercise, and glucose levels tend to rise secondary to counter-regulatory hormones.[53] After training, insulin sensitivity also increases and remains high for about 24 hours, and with prolonged strenuous exercise, insulin sensitivity increases for up to 48 hours.[53]

Insulin adaptations can also be related to insulin-like growth factors (IGF-1) given their importance in protein synthesis during resistance training and muscle hypertrophy.[50] However, the acute responses of this hormone remain unclear in the literature. In general, acute elevations following short resistance training periods may be delayed until GH-stimulated synthesis and secretion from the liver take place.[50]

Chronic adaptations are often evaluated in the context of IGF-1 rather than pancreatic insulin hormone. Similarly, IGF-1 shows no chronic adaptations in response to resistance training.[50] In general, resistance-trained men had higher resting IGF1 than non-trained men.[50]

In women, higher serum elevations of resting IGF-1 during high-volume training are seen in studies with longer protocols.[50] It also appears that the volume and intensity of training are important for chronic adaptations of IGF1, as one report showed reductions in IGF1 during strenuous training.[50]

Catecholamines

Catecholamine changes after exercise have mainly been studied in the context of acute adaptations. An acute bout of resistance training increases plasma concentrations of epinephrine, norepinephrine, and dopamine.[50] In addition, before a strenuous exercise, the plasma concentration of catecholamines also increases.[50]

Similar effects also occur when endurance-trained individuals are compared to sedentary subjects in response to the same relative intensity exercise. This phenomenon is described as the "sports adrenal medulla", a long-term adaptation of an endocrine hormone to physical training.[54] However, chronic adaptations remain unclear, although research findings show that training reduces the catecholamine response to resistance exercise.[50]

Cortisol

Cortisol concentrations significantly increase during an acute bout of resistance training in both sexes. The research shows that this response is independent of training status in the adolescent population.[50] Particularly, metabolically demanding protocols of moderate to high intensity, high volume, and short rest periods report the greatest acute cortisol response.[50] Similarly, the number of sets per exercise appears to influence responses as well, with four to six sets of resistance exercises resulting in significant results compared to two sets.[50]

Cortisol resting levels reflect long-term training stress. Chronic resistance training is not a factor that produces consistent patterns of cortisol secretion either. The evidence consensus determines that acute cortisol responses are associated with metabolic stress, whereas chronic adaptations are related to protein metabolism and tissue homeostasis.[50]

Other Hormones

Estrogen

Estrogen concentrations acutely increase in most women after endurance and resistance exercises and usually decrease by the 30-minute recovery.[55] In premenopausal females, similar results exist.[56] Another study assessing postmenopausal females found that anaerobic exercise significantly improved estradiol level and lean mass than aerobic exercises, despite having more than twice as many aerobic sessions throughout the study.[57] The effects of acute estrogen release may relate to reducing exercise-induced muscle damage and improved recovery.[58] Furthermore, inconclusive data remain on chronic responses to exercise and training on estrogen.

Glucagon

Acute bouts of exercise can lower blood glucose concentration for 2 to 48 hours post exercise and improve insulin sensitivity for up to 72 hours after cessation of any given exercise bout.[53]

When plasma glucose declines, the sensitivity of the liver to glucagon also improves.[53] In response to prolonged exercises, the decrease in insulin and increase in glucagon also attenuates.[53] Additionally, acute aerobic exercises show significant increases in glucagon concentrations irrespective of metabolic state.[53]

Thyroid Hormones

Exercise intervention studies report that thyroid hormone levels decrease in response to resistance and endurance training.[59] Several analyses indicate that physical activity modulates both circulating TSH and T4 and the magnitude of TSH response to lower T4 levels.[59] At low levels of T4, physically active adults appear to produce less TSH.[59] Previous studies also reported that aerobic exercise increases total serum T3 and T4.[60]

Consequently, moderate-intensity exercise can increase T4 concentration in the blood.[61] Aerobic exercise is associated with a progressive decrease or an improvement in serum thyroid stimulating hormone (TSH).[62] On the contrary, 12 weeks of aerobic exercise show insignificant changes in the plasma level of TSH, T3, and T4 hormones among sedentary women.[63]

Summary

The endocrine system includes hormones (estrogen, testosterone, etc.), the glands that produce them (hypothalamus, pituitary, etc.), and the receptors in the body that respond to hormones.

Hormones have a strong role in influencing the body’s nervous system and exercise stimulates hormones dues to system stressors for both men and women, although there are hormone differences between the genders due to physical differences.

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Chapter 6

Biomechanics and Kinesiology

Elias Malek, MS

Introduction

The word kinesiology stems from the Greek words Kinesis "to move" and –ology "to study." Kinesiology is defined as the scientific study of human movement and how physical activity, sport, and exercise affect quality of life and sports performance.

Kinesiology focuses on the physiology behind the adaptations that are created as a result of chronic and acute physical activity or exercise. Kinesiology covers a broad range of topics, ranging from cardiovascular adaptations to single bouts of exercise to the effects and adaptations to exercising at altitude.[1]

As a personal trainer, it is important and necessary to understand both the gross anatomy and the intricacies of the physiology of the body.

Properly coaching and designing exercise programs for clients requires a basic understanding of biomechanics and kinesiology to ensure you select the best exercises for each client and keep them safe while they perform each exercise technique.

Anatomical Terms

These terms are used to describe the different positions of specific anatomical structures, anatomical locations, movements, and positions.[2,3]

- Anatomical position – standing upright, facing forward, hands to the side of the body with the palms facing forward, legs parallel with the feet flat on the floor facing forward
- Anterior – towards the front of the body
    - The sternum is anterior to the spinal column
- Posterior – towards the back of the body
    - The hamstrings are part of the posterior chain muscles
- Midline – the imaginary median line that spans from the head to the foot and serves as a reference point in the body
- Medial – towards the midline of the body
    - The sternum is medial to the rib cage
- Lateral – away from the midline of the body
    - Bending the neck to either side of the head is lateral flexion
- Superior – toward the head, above
    - The head is superior to the neck
- Inferior – toward the feet, below
    - The diaphragm is inferior to the heart
- Proximal – closer to or toward the torso

    - The elbow is proximal to the hand
- Distal – away from the torso
    - The toes are distal to the knee
- Cephalad – toward the head
    - The cervical vertebrae move cephalad from C7 to C1
- Caudal – toward the tail or feet
    - The cervical vertebrae are caudal from C1 to C7
- Superficial – toward the surface or skin of the body
    - The skin is superficial to the muscles
- Deep – toward the inside or core of the body
    - The organs are deep to the skin
- Origin – the proximal attachment of a muscle
    - The biceps brachii originates on the coracoid process
- Insertion – the distal attachment of a muscle
    - The quadriceps insertion point is the patella
- Prone – lying flat, facing downward, laying on one's stomach
    - The patient was in a prone position for the spinal surgery
- Supine – lying flat, facing upward, laying on one's back
    - The patient was sleeping in a supine position

Planes of Motion

The human body is divided into three planes of motion: the sagittal plane, the frontal plane, and the transverse plane. Most movements occur in multiple planes of motion to varying degrees, with the majority of the movement occurring in the primary plane.

The sagittal plane divides the body into left and right sections. Movements in the sagittal plane include squats, deadlifts, rows, horizontal pressing, and most fundamental gross motor exercises.

The frontal plane divides the body into front and back sections. Movements in the frontal plane include side steps, lateral lunges, and lateral dumbbell raises. Virtually all lateral movement occurs in the frontal plane.

The transverse plane divides the body into upper and lower sections. Movements in the transverse plane include Russian twists, golf swings, and rotational chest passes. Most athletic movements that involve rotational movement occur in the transverse plane.

Sagittal Plane

Divides body into left and right

Movements in this plane	Exercises in this plane
Forward and backward movements	Running, walking
Elbow flexion and extension	Bicep curls
Knee flexion and extension	Hamstring curls
Shoulder flexion and extension	Pressing movements
Ankle dorsiflexion and plantar flexion	Calf raises
Hip flexion, extension, and hyperextension	Squats, deadlifts

Frontal Plane

Divides the body into front and back sections

Movements in this plane	Exercises in this plane
Side to side motions	Lateral lunge
Trunk side bending	Oblique crunch
Hip and arm abduction/adduction	Side steps, lateral raise
Ankle inversion/eversion	Ankle rotations
Radial and ulnar deviation	
Neck lateral flexion	
Scapular depression/elevation	
Scapular upward and downward rotation	
Scapular protraction/retraction	

Transverse Plane

Divides the body into upper and lower sections

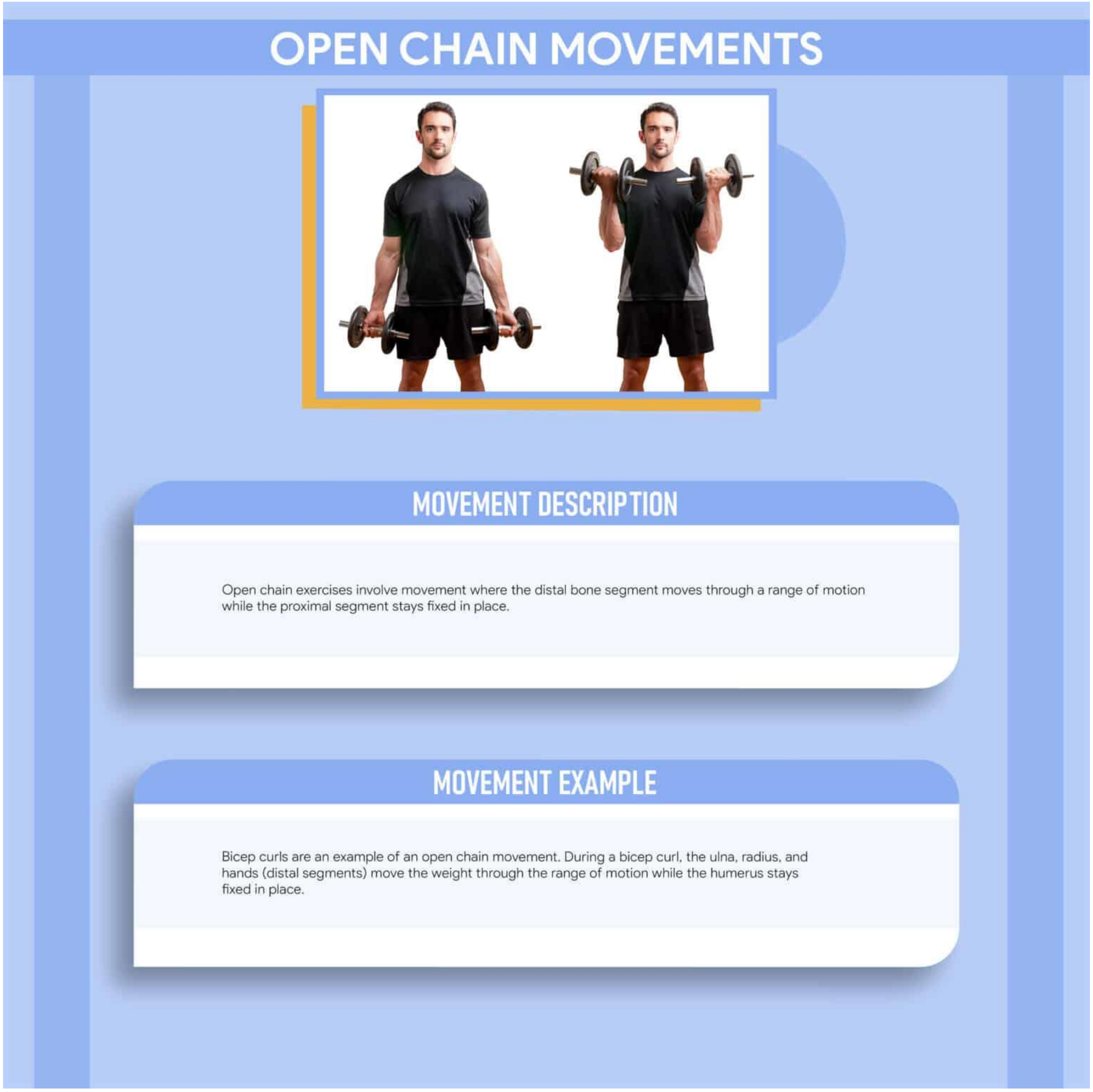
Movements in this plane	Exercises in this plane
Twisting or rotational motion	Russian twists, swinging a bat
Internal/medial rotation	
External/lateral rotation	

Open-Chain vs Closed-Chain Motion

Open-chain motion refers to the movement of the distal segment of a bone about a fixed proximal segment. An example of an open-chain movement would be doing a bicep curl with a dumbbell.

A closed-chain movement refers to the movement of the proximal part of a bone about a fixed distal segment. An example of a closed-chain movement would be a push-up.

Coaching Application



An understanding of the planes of motion and anatomical reference points is important for personal trainers for several reasons.

Breaking down complex movements into an understanding of the muscle actions, including both movement and stabilization, allows a coach to have a more nuanced understanding of technique observation and coaching when demonstrating, cueing, and correcting movements.

Furthermore, when designing exercise programs, coaches should generally include exercise movements in all planes of direction – this can include both isolated exercises as well as compound movements with multiple planes of motion.

Finally, an understanding of biomechanics is important for a trainer explaining to their clients why they selected specific exercises in the event their client asks about that aspect of the exercise program.

Muscle Actions and Muscle Action Spectrum

Every muscle in the body has an origin and an insertion. The origin of a muscle is the fixed end of the muscle. The origin of a muscle attaches to the bone, and this end of the muscle does not move.[2, 3] The insertion of a muscle is the site at which the muscle connects to the bone that moves.

When referring to muscles and the movement they create, they are classified as either primer movers/agonists, antagonists, or synergist muscles. The prime mover or agonist muscle is the primary muscle responsible for a given movement. The antagonist muscle performs the opposite movement as the prime mover, and in some cases will resist the action of the agonist muscle. The synergist muscle or muscles will assist or help the agonist muscle with movement.

Muscle contractions are categorized by the changes in the length of the muscle during the contraction. A muscle fiber is going to create tension through myosin and actin cross-bridge cycling. When a muscle is under tension, the muscle can remain the same length, shorten, or lengthen. When referring to a muscle contraction, the assumption is that the muscle is shortening, but the contraction only means that the individual is generating tension within the muscle fiber.

Muscle contractions can be categorized into 5 actions:

- isotonic contraction
- concentric contraction
- eccentric contraction
- isometric contraction
- isokinetic contraction

Isotonic Contraction

An isotonic contraction maintains constant tension in the muscle while the muscle lengthens or shortens. An isotonic contraction can only occur when the maximal force of contraction exceeds the total load on the muscle.

For example, during a bicep curl, the biceps muscle will only isotonically contract if the weight is not too heavy.

Examples of isotonic exercises include dumbbell bicep curls, barbell squatting, push-ups, and most traditional resistance exercises using weights.

Isotonic contractions are further categorized as concentric or eccentric.

Concentric Contraction

Concentric contraction occurs when the muscle action produces a force that can overcome an external load. To generate a concentric contraction, the muscle force produced must be greater than the load that it is carrying.

Consider the upward thrust during a bench press. In this case, the barbell acts as the external resistance against the pectoralis muscle. During the upward thrust, the sum of the force produced is greater than the resistance of the barbell pushing downward.

This results in the bar being moved upward or lifted by a concentric contraction.

Eccentric Contraction

An eccentric contraction is generated when the muscle is lengthened or elongated while still generating force. During an eccentric contraction, the resistance applied to the muscle is greater than the force generated by the muscle, thus lengthening the muscle.

Cross-bridge cycling still occurs in this example. During exercise, the eccentric contraction is often referred to as the negative. For example, during a bicep curl, trainers may coach their client to focus on slowing down during the negative action of the bicep curl.

They are instructing their client to stay in the eccentric action longer to increase the time under tension. Post-exercise muscle soreness is produced mainly by eccentric contractions. In fact, muscle tension is higher during an eccentric contraction than in isometric or concentric contractions.

Isometric Contraction

The word isometric means “same length.” The key aspect to note here is that the muscle length is not what is staying the same. The joint angle remains constant. The word contraction means shortening so an isometric contraction does involve internal processes that shorten the muscle fibers.

The purpose of isometric contractions in exercise is often stabilizing the joints and spine so that prime movers can safely and effectively apply muscle force to the resistance. For example, during a squat the hip adductors and abductors contract isometrically to prevent unwanted movement in the frontal and transverse planes.

Isometric exercises can be done with or without weights. Isometric exercises are useful because they require relatively minimal equipment and can be done by most of the general population regardless of physical activity levels.

The elbow plank is a classic example of an isometric exercise. During a plank, the client is resisting gravity using their body weight. Resisting the pull of an elastic band without additional movement is another common example of isometric muscle action.

Isokinetic Contraction

An isokinetic muscle contraction occurs when the speed of the muscle contraction remains constant while the length of the muscle changes. During an isokinetic contraction, the force that is produced by the muscle does not remain constant. The force of the contraction is modulated by the position of the joint in its range of motion and the participation effort of the subject.

An isokinetic contraction differs from an isometric contraction in that an isokinetic contraction retains a constant speed while an isometric contraction has a constant muscle length. Isokinetic muscle loading is similar to isometric contractions in that they can be either concentric or eccentric. In an isokinetic concentric contraction, the muscle shortens or lengthens while under load.

An interesting application of isokinetic contractions comes in the form of very expensive biomechanical equipment. An isokinetic dynamometer is a machine that is used to control the speed of a muscle contraction.

These devices are typically used in research settings as well as rehabilitation settings. The ability to modulate and control the speed of contraction of any joint in the body allows practitioners and researchers to determine things such as muscle fiber type, create a force velocity curve, and determine the optimal length of a joint angle for force production.

Most isokinetic exercises require an isokinetic dynamometer or other specialized equipment to keep the speed of the contraction constant.

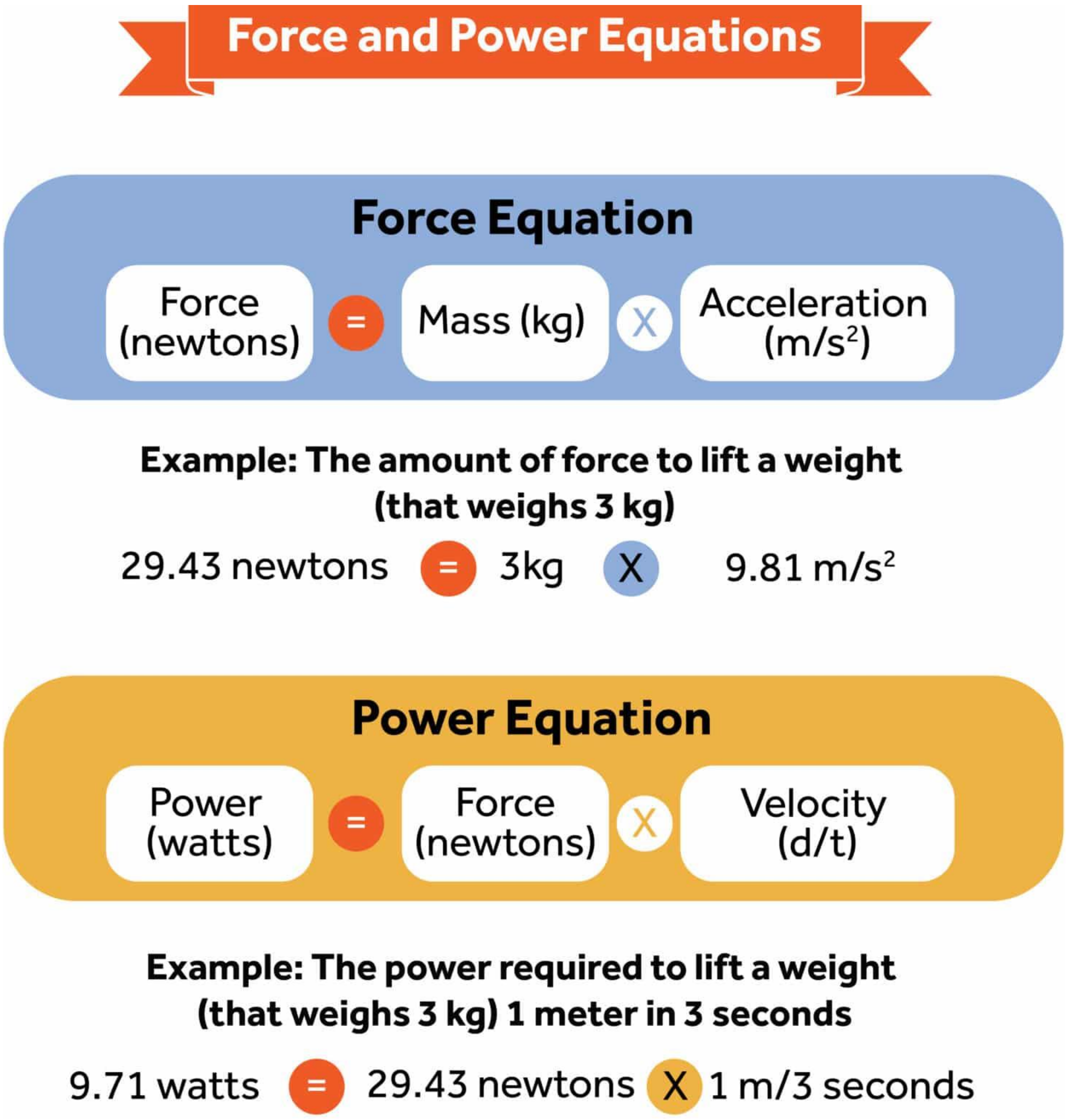
There are some bodyweight exercises that can be performed such as squats where the individual focuses on moving through the exercise at a constant speed. However, most of the time, isokinetic exercises are going to be performed as part of a rehabilitation or recovery program.

Biomechanical Definitions

Force, Muscle Force, and Power

To standardize terms for the measurement of energy, force, work, and power, scientists use System International (SI) units. Force is a simple way to represent load in biomechanics and can be defined as the action of one object to another.

Force can be external or internal. Force is measured as the product of the mass of an object in kilograms and acceleration in meters per second squared. When calculating force in most traditional resistance exercises, the acceleration used is going to be gravity, which is commonly approximated as $9.81 m/s^2$.



There are multiple types of force that can act on the human body. These include:

- Motion forces
- Internal forces
- External forces
- Reactionary forces

Biomechanics focuses both on how the different forces act on the musculoskeletal system as well as how the body tissue responds to these forces.

Internal forces are produced by muscle action within the body and create movement. External forces act on the body and in practical terms are typically the ground force acting on the body during ground contact as well as the external resistance of weights. In the case of swimming, running, and cycling, fluid resistance from the water or air, respectively, adds another measurable external force.

Internal movements cannot cause a change to the motion of the center of gravity of the human body without the assistance of external forces. What this means is that the human body is only able to change direction of movement if it is in contact with another external object. For example, a goalkeeper jumping to catch a penalty kick cannot change direction after the first jump until they make contact with the ground. Upon landing, the goalkeeper can then push against the ground and change the direction of motion.

In this case, the ground is the external force that will allow the goalkeeper to change the direction of motion. The same internal muscle forces activated without the ground present cannot result in a change of motion.

Internal Forces

Internal forces are the result of muscle actions, specifically the cross-bridges formed by actin and myosin during muscle contraction, that result in muscle force generation. The outcome of this tension is an internal force within the human body. This internal force ultimately acts on the bones of the skeletal system via the tendons, resulting in angular motion about a joint.

External Forces

External forces are the forces that result from the human body interacting with its environment. They can be categorized into contact forces and non-contact forces. From a biomechanics perspective, most forces humans encounter will be external contact forces occurring at the site of contact as the limbs interact with the ground.

The prime example is foot contact with the ground that occurs with any standing or walking-based activity. The most common non-contact external force is gravitational force, which acts on all objects on Earth via the Earth's gravitational field. Gravity affects objects even if they are not in direct contact with the ground.

Power

The definition of power in the context of biomechanics is the rate at which mechanical work is performed. Power is measured in watts (W). A watt represents 1 joule per second rate or energy production or consumption.

To find the amount of energy consumed in joules, one would multiply the power output in watts by the number of seconds that output was sustained. The power produced when lifting an object, such as a piece of resistance equipment, can also be calculated if the mass of the equipment, vertical distance lifted, and time to complete the movement are known.

When analyzing a movement as simple as moving a dumbbell vertically, an individual must oppose the force of gravity that is acting on the mass of the dumbbell through a specific displacement, or change in height, during a duration of time.

To determine power from this, one would take the product of the force and the displacement to determine the work in joules which could then be divided by the time it took to complete the movement to determine the power in watts.

The simplest equation to determine power is as follows: power = force x velocity.

Power is typically used to determine output across time. For example, when on a cycle ergometer, power is measured in watts as a metric as well as total work done in joules. Overall, power output is a useful metric when prescribing exercise intensity and measuring improvements in cardiorespiratory fitness.

Length-Tension Relationship

The length-tension relationship explains the difference in tension production as a product of the length of the muscle changes. As a muscle increases in length, the force that the muscle is producing will also increase. This happens because of the interaction between the cross-bridges of our muscles. At shorter lengths, there are fewer cross-bridge interactions, resulting in reduced tension development.

At higher lengths, it’s possible to lengthen too much and decrease the number of cross-bridge interactions, reducing the potential for contractile protein binding and decreasing the muscle’s force-generating capacity.

At the optimal length of the muscle, there is a maximal number of cross-bridge interactions, which results in maximal tension or force development.

Force Velocity

The link between force and velocity is illustrated by the force-velocity curve. Because of the inverse nature of this connection, the force will decrease as velocity rises. For specific adaptations, a coach must be aware of the physiological and biomechanical distinctions between recommending a 1RM deadlift and a 5RM jump squat.

Understanding this relationship is crucial since one exercise will result in larger forces and lower velocities than the other. A decrease in the amount of time available for cross bridges to form is assumed to be the cause of this trade-off between force and velocity. More time results in more cross-bridges, and more cross-bridges mean a greater contractile force.

Slower-paced activities, therefore, enable the athlete to create more cross-bridges and generate more force. Exercises performed at a higher velocity give cross bridges less time to develop, resulting in less force being produced. As a result, distinct exercises and intensities have been divided into different force-velocity curve segments.

Levers

A lever system is a rigid rod that moves at a fixed point called a fulcrum when a force is applied to it. Movement in the human body is possible using lever systems formed by the muscles and joints working together. Understanding levers in the body helps a coach understand how movement is possible.

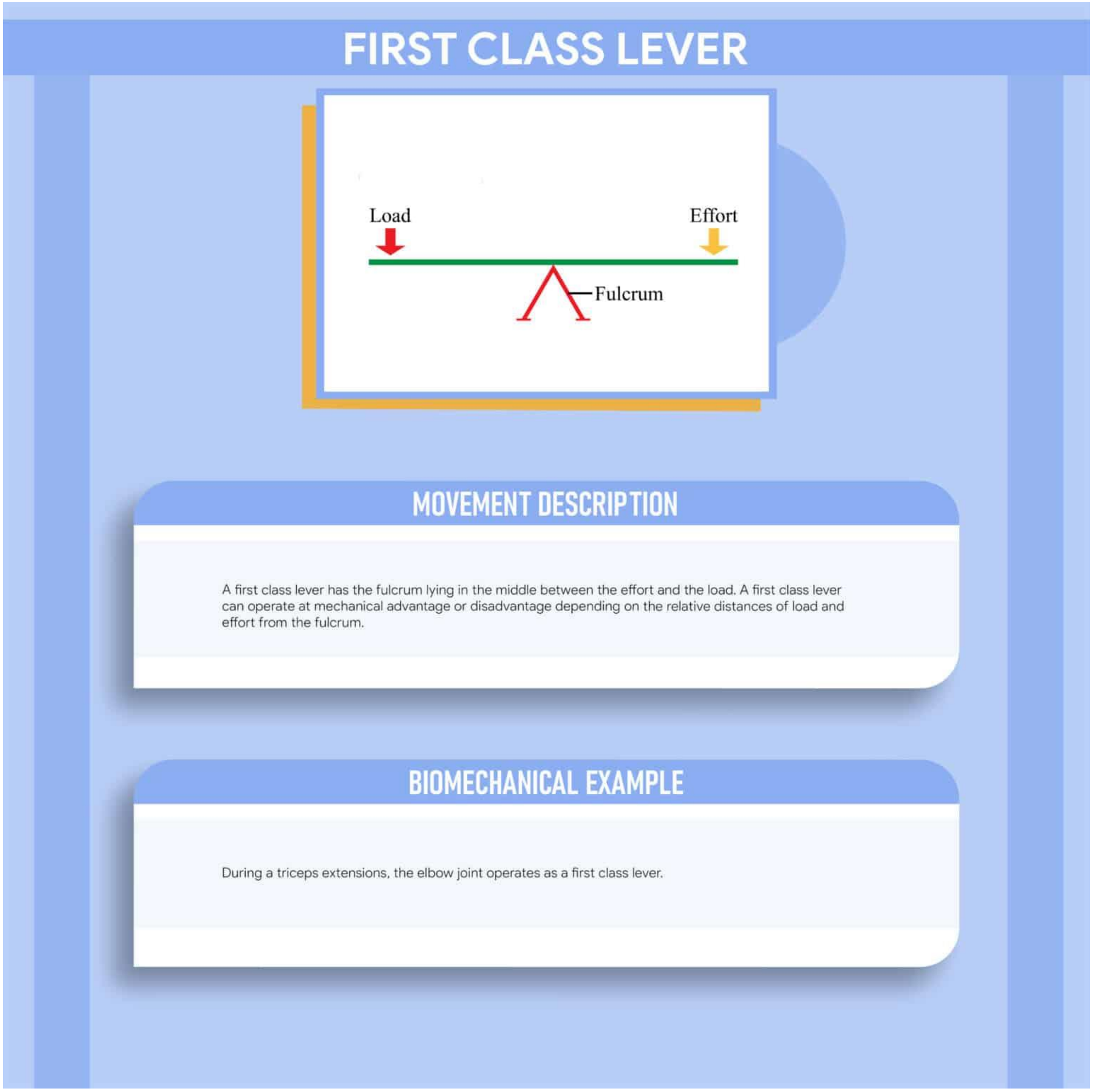
Muscles are attached to bones by tendons. The bones of the skeleton act as lever arms, with the joints as pivot points, allowing muscles to produce movement. Any lever system consists of three parts: effort, load, and fulcrum. The effort to move weight is provided by the muscle, the load is provided by the weight of the body and any added resistance, and the fulcrum is the joint itself.

In a first class lever, the fulcrum is the middle component and lies between effort and load. There are few exercises that use a first-class lever system in the body; triceps extension at the elbow is one example. Elbow extension is seen during a throwing motion or tennis stroke, as well as a triceps cable extension.

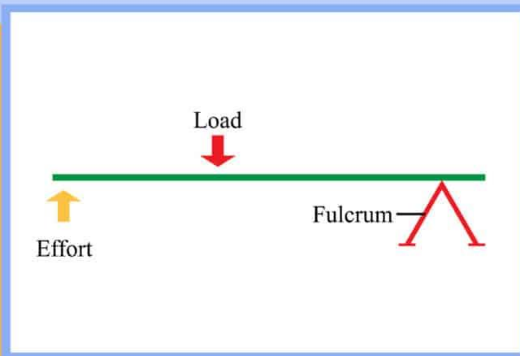
In a second class lever system, the load is the middle component and lies between the fulcrum and the effort exerted. Exercises involving plantarflexion at the ankle (raising the heels) are second class lever systems. Examples include calf raises or plantarflexion when jumping upwards while performing a layup in basketball. The second class leverage system tends to increase effort effectiveness. That means it’s more effective at overcoming resistance than it is at creating speed.

Most of the movements of the human body fall into the third class lever system. In a third class lever system, the force is the middle component, lying between the fulcrum and the load. There are many examples of lever systems that involve flexion and extension at the knee joint.

These movements are involved in running, jumping, and kicking. During flexion of the knee, the point of insertion of the hamstrings on the tibia is the point of effort, the knee joint is the fulcrum, and the weight of the leg is the load. The third class lever system is used to increase body speed and allow for a wide range of motion.



SECOND CLASS LEVER

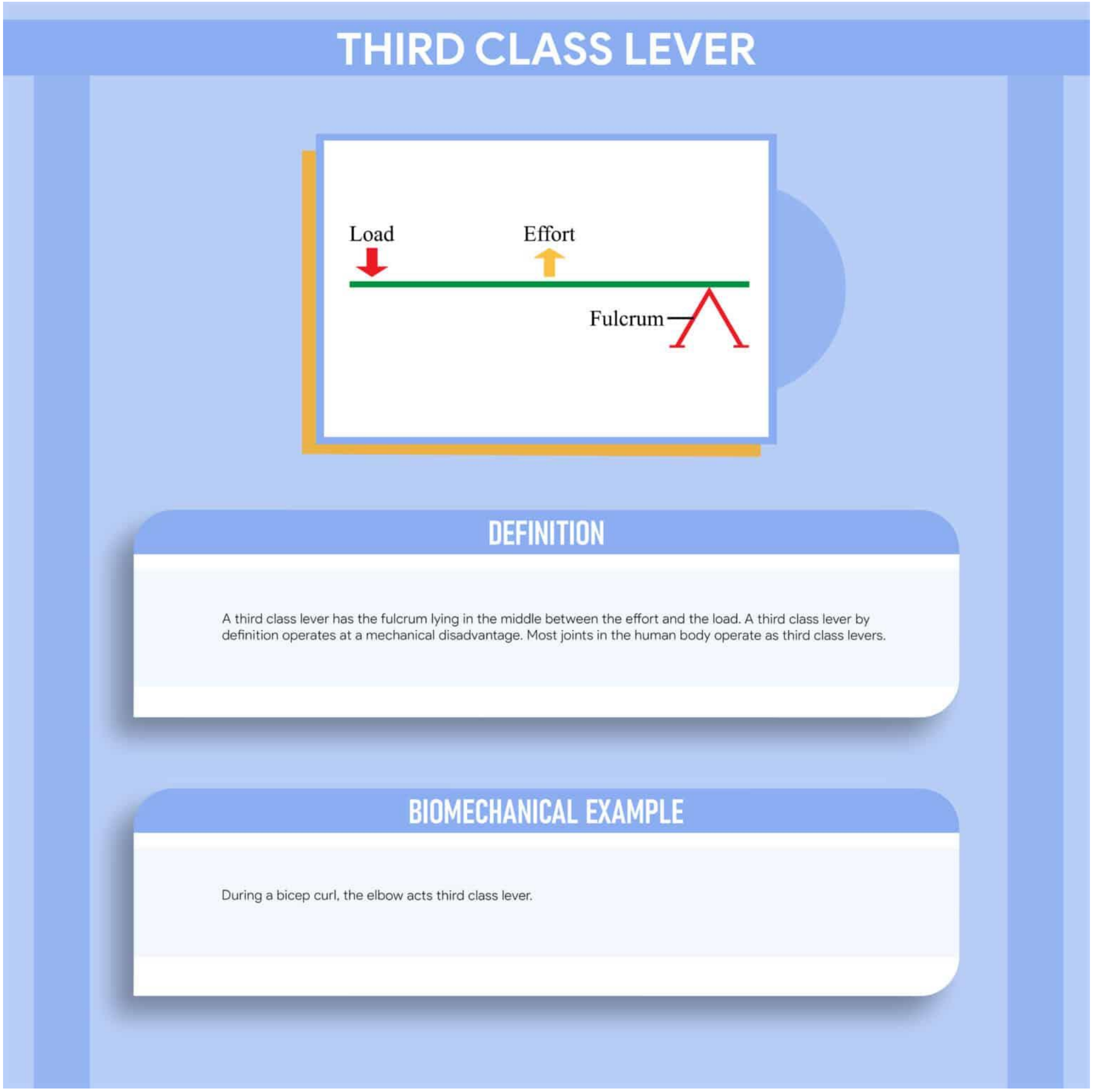


DEFINITION

A second class lever has the load lying in the middle between the effort and the fulcrum. A second class lever by definition operates with a mechanical advantage.

BIOMECHANICAL EXAMPLE

During plantarflexion activities, such as a calf raise, the ankle joint operates as a second class lever.



Torque and Rotary Motion

Torque is another key biomechanical concept. In physics, torque is defined as the rate of change of an object's angular momentum. The following will explain what this implies when applied to biomechanics and kinesiology.

Since all human movement occurs around a pivot point, the rate of movement is most accurately expressed as the rate of change in angular momentum.

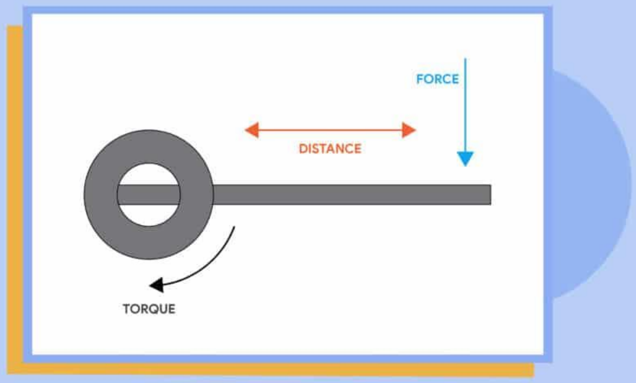
An object will move in the same linear direction as the force if a force is applied to it in a linear direction and the object is not fixed at any point. For instance, when someone pushes a book across a desk, it will glide in the same direction as their hand, if they were to push close to the center. Linear motion is the name given to this kind of motion. Forces that push or pull cause linear motion.

The body can also move in a way known as rotational motion. When a force is given to one part of an object while another part remains immobile, the object rotates. When a muscle pulls on one end of a bone while the other end is fixed, rotational motion occurs in the body.

The non-fixed end moves as a consequence. For instance, there is rotary motion at the knee joint when the proximal end of the hamstring muscles is held stationary at the pelvis while the distal end pulls on the tibia and fibula during knee flexion.

A force that is created by rotating motion is known as torque. Torque is mathematically defined as the product of multiplying the force exerted on the object by the distance of the force from the fulcrum or pivot point.

TORQUE



DEFINITION

In physics, torque is the rotational equivalent of linear force and represenrs the capability of a force to produce a change in the rotational motion of the body. Torque typically manifests as the rotation of an object around a fixed point, such as in levers.

IMPLICATIONS OF TORQUE IN HUMAN MOVEMENT

1. The muscle force required to overcome a given weight increases or decreases throughout the range of motion due to the change in distance between the fulcrum and resistance, which changes the mechanical advantage of the muscle and joint. The location in the movement with the least mechanical advantage manifests as the "sticking point," and is typically the point where muscle failure occurs during a failed repetition.

2. The specific limb length and muscle insertion points vary between individual humans. People with longer bones or tendon insertions closer to joints cannot lift as much weight because in either case, the resistance ends up further from the joint relative to the location of the muscle force, reducing the mechanical advantage. However, these individuals do have an advantage when it comes to speed and acceleration during non maximal strength activities.

Summary

Biomechanics and kinesiology are key topics to understand as a fitness professional.

Understanding the planes of motion allows for better exercise programming in terms of both performance and injury prevention. Furthermore, being able to recognize the movement in the different planes aids in technique observation and cueing for fitness clients.

Basic physics, as it applies to the human body, also assists personal trainers in understanding the various forces involved in exercise and their implications in terms of progress tracking, athletic performance, and preventing injuries.

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Chapter 7

Communication Skills for Fitness Professionals

Quentin Washington, MS

Introduction

Communication skills are vital for all fitness professionals. From closing sales with prospective clients, to instructing technique and guiding clients through behavioral changes, interpersonal communication is a constant aspect of being a great personal trainer.

Personal trainers, instructors, and coaches with good communication skills give vital information to their clients in training sessions and process feedback from those clients seamlessly. Effective communication between client and trainer continuously loops back and forth: the trainer provides information, and the trainee provides feedback, which allows the trainer to consider and make proper adjustments.

Fitness professionals need to keep that loop open by developing their communication skills to encourage discussion and openness. In addition, effective communication between coach and client expands outside of training. This chapter will cover communication skills that will provide success for a trainer.

The Importance of Communication Skills

Healthcare industry research shows that better relationships between clients and healthcare professionals lead to better health outcomes. Warmth, nursing, negativity, and clear listening lead to greater patient satisfaction with their healthcare professional.[1]

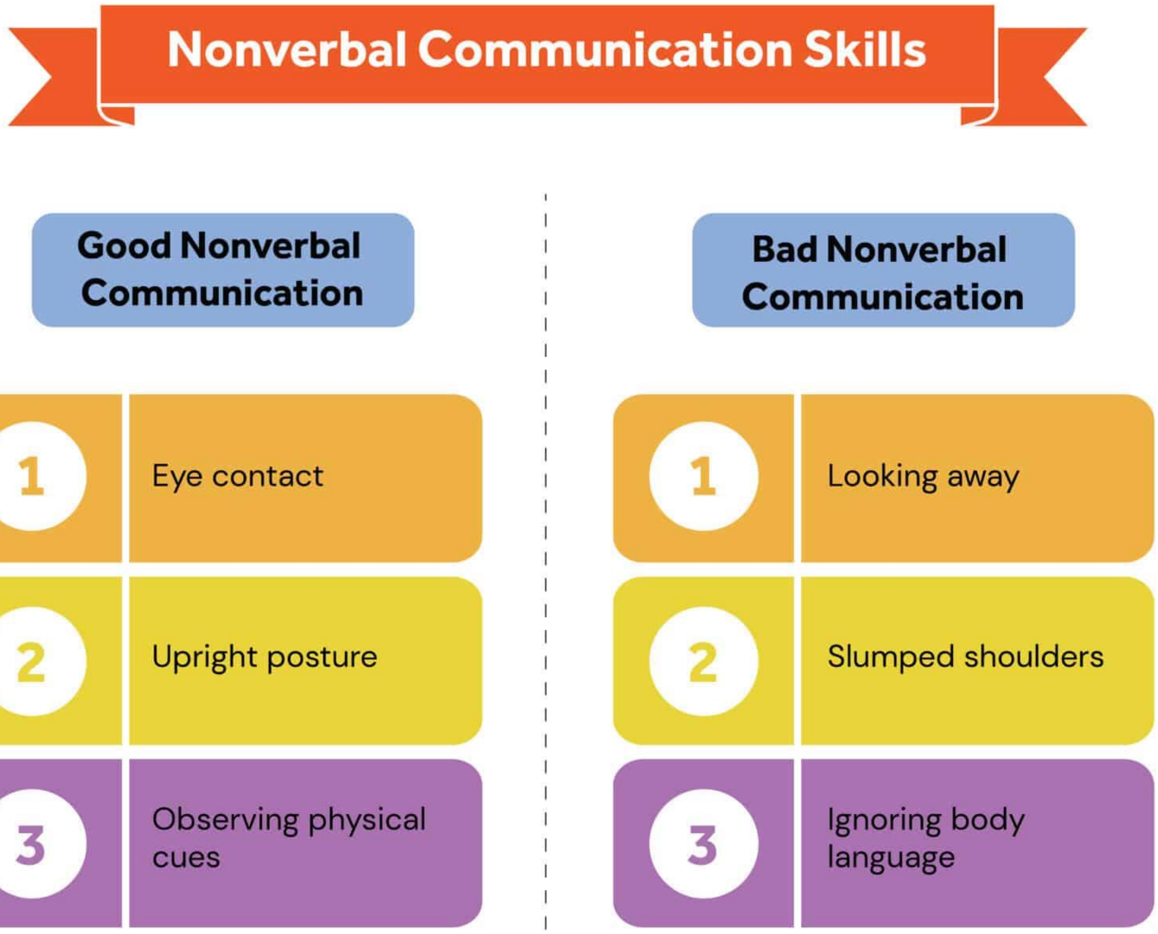
Communication has two components: non-verbal and verbal.

Nonverbal Communication

Nonverbal communication describes messages that are conveyed outside of words. Information delivered by a trainer hunched over with a sullen face may be interpreted differently than that from a trainer standing up tall carrying a confident look on their face.

Nonverbal communication also includes the small things the body conveys as well, such as where an individual looks when they deliver information. For example, whether the individual is looking into the other person's eyes or looking away when they are speaking makes a big difference in the effectiveness of the communication.

The way in which a fitness professional's body language and other forms of nonverbal communication are interpreted by the client can make a huge difference as to whether a person signs up for or continues with training.



Active Listening and Verbal Communication

Active listening is a form of verbal and nonverbal communication that shows the other individual in the conversation that the coach is listening and taking into account what the client is saying. Active listening reduces defensive discussions and arguments, which improves both parties' abilities to communicate openly.[3]

Active listening vitally builds up relationships and trust between individuals. Active listening includes nodding, repeating information, making eye contact, focusing on the other person as well as other facets like displaying care for the client.

By actively listening, the client can see that their coach cares about what they have to say and by extension, cares about them. Active listening has four main components that coaches will find effective:

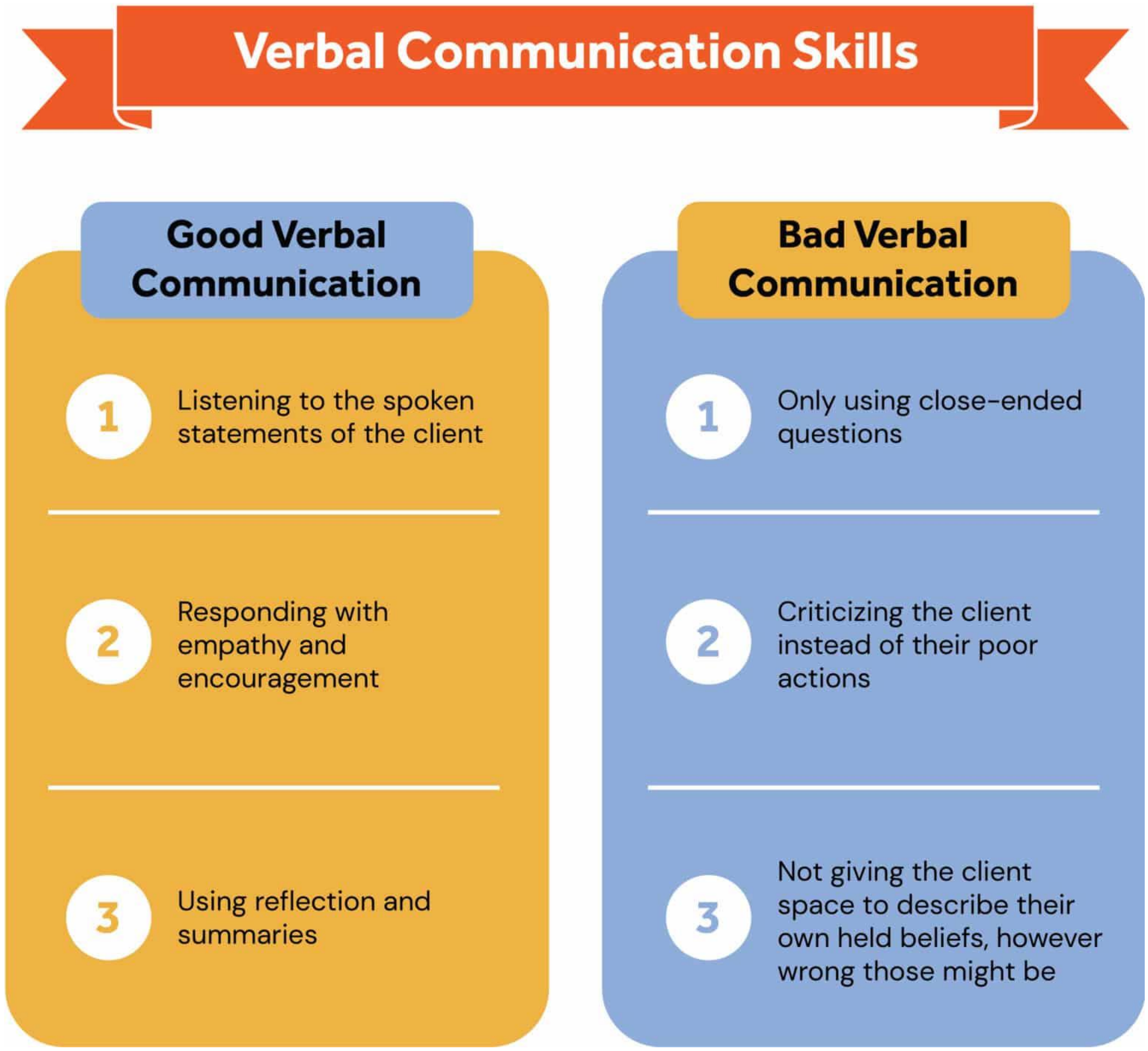
1. Listening to the spoken statements of the client

2. Observing nonverbal communication
3. Listening to the context of the client's apprehensions
4. Listening to the context of the client's statements that may need to be challenged[4]

The first part is simple enough: listen to the spoken statements of the client. This means the trainer pays attention to what the client is saying. The next part, observing nonverbal communication, can take time to master. However, with some practice, fitness professionals can start to pick up on the subtleties of body language.

A client with a hunched back and arms crossed may be displaying apprehension and closed off to suggestion. In this case, the coach or trainer should focus on developing the relationship so the client feels like he or she can trust the coach.

The third part requires the trainer to pay attention to the spoken and the deeper emotional connotations the client is displaying. Often spoken words do not convey the entire picture and the client may not be able to communicate their apprehension effectively or they might be hiding something they're embarrassed about.



On the other side of that coin, sometimes, a trainer or coach needs to challenge an opinion of a client. When this happens, the client must feel seen and respected. The trainer should allow them to describe what they know, which will give the professional a chance to understand the client's current beliefs.

Once the trainer positively affirms the correct beliefs, the coach can then address whatever myths or misinformation the client has described, during either that session or on subsequent workout days. Also, the trainer should give the client an opportunity to bring up their hesitations and concerns.

The next step of effective active listening requires empathy. The ability to share and understand each other's feelings builds a more effective relationship. Both parties share. Both parties hear one another and feel heard.

When the coach shows they care about what their client has to say and feel, the client responds openly to the trainer. This enables both sides to speak directly. The trainer is the leader in this relationship, but the client should also be encouraged to take an active role as well.

A coach obviously needs to ask their clients questions but different kinds of questions can have a different effect on the relationship between client and coach. Close-ended questions, such as "what is your name" are unavoidable and provide important information to the coach.

However, open-ended questions allow for more engagement between the client and the coach. The kinds of interactions that open-ended questions allow for help build a healthy collaborative relationship that makes for a successful coach-client relationship.

How to Build Rapport

Rapport is a close relationship where both parties can communicate well. Developing rapport is a multifaceted process that uses important communication skills to help improve the client-coach relationship.

By creating rapport, a trainer and a client more easily address and solve problems that may arise. Building rapport requires a trainer's empathy and self-awareness. To build and maintain rapport, a trainer should avoid arguments and instead use active listening and reflection, since arguments can be damaging to the trainer/client rapport.[5]

The coach needs to be able to incorporate previous experience when appropriate and understand when their previous experience does not apply. Reflection is another powerful tool that involves expressing the meaning in a reply to the speaker to show them their words are understood. In the context of personal training, this offers a chance for the client to correct the trainer if they misunderstood the meaning of their words or a chance to confirm if the trainer is correct.

It may take some time for the trainer to become fluent with reflection, but in time, it can be a powerful tool. It should be noted that reflection, while a powerful tool, can be ineffective based on certain individuals.[6]

The natural evolution of reflecting is summarizing. Summarizing involves a series of reflections that highlight important parts of the conversation. It shows a deep understanding of the conversation and offers another chance for the client to correct or clarify any information.

A trainer must convey compassion and respect for the client's differences while appreciating their similarities. A trainer should be able to discuss differences in opinion without arguing with the client and ultimately respecting the client's opinion.

The trainer should also be able to discuss why something may not be working for the client in a manner that is still respectful and criticizes the actions of the client, not the client themselves. The trainer should motivate their clients with the knowledge they have accrued over time as well as leveraging their communication skills noted in this chapter to improve rapport.

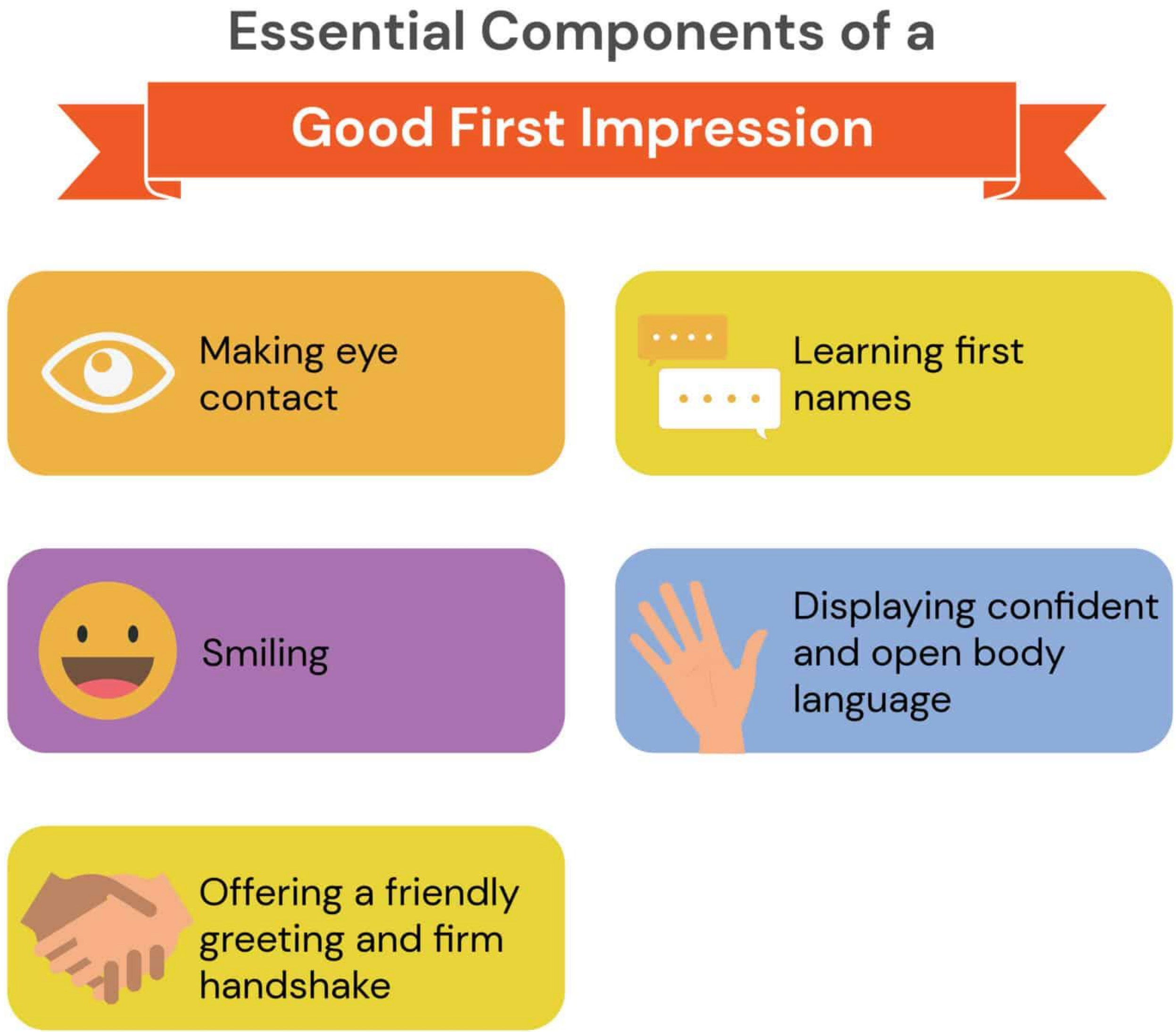
The Initial Client Interview

Clientele will come into the initial interview with certain expectations. While many of those expectations will be different between clients, many overlap. The client expects their coach or trainer to be knowledgeable and confident, which is best conveyed through both verbal and non-verbal communication. In almost every case, the first impression will determine if the trainer will be allowed the opportunity to train their prospective client.

A good first impression has many components: making eye contact, smiling, a friendly greeting with a firm handshake followed by the trainer introducing themselves and then getting the prospective client's name, using the client's name, and displaying confident and open body language.

While most of these are self-explanatory, using confident and open body language may require practice from trainers who do not naturally possess this skill. Confident body language requires the trainer to be relaxed and stand up straight with their shoulders back and the head pointed forwards and the trainer should keep a smile or neutral facial expression.

Trainers who present the appearance of giving the client their full attention when they are speaking as well as refraining from closing their chest, as in crossing their arms in front of their chest, will be more successful. This last part is crucial for open body language. It displays to the client that the trainer is open and receptive to them and what they have to say.



In addition to body language, clients will also notice the trainer's appearance. While a suit or business casual wear is not necessary, being well-groomed and having clean clothes can have a positive impression on the client.

Throughout the interview, the trainer should be fully engaged in the conversation, asking both general and specific questions to better understand the client. Examples of general questions include asking about injuries or conditions or how much experience the client has while specific questions fall along the lines of examining specifically what the client said.

Asking the client what kind of movements irritate their injury or what motivated them to start their fitness journey originally facilitates finding out information that will be integral to the training process. This will show the client that the trainer cares enough to dig deeper and that the trainer listens to them.

If the client has no interest in sharing deeper information outside of training, the trainer should respectfully understand and continue to focus on health and fitness concerns.

Fitness Sales Process

Once a personal trainer or fitness coach establishes themselves, they need to be able to sell and market their services in order to be successful individually or as a part of a company or training facility. A trainer needs to be able to generate leads and take prospective clients through the sales process so that the trainer has clients to train.

Lead Generation

For many trainers, lead generation is the most difficult part of the sales process. Every personal trainer and coach at some point has to determine where they will find clients. Some independent trainers may start by offering free training to close friends and family initially before charging them.

In terms of growth, some trainers may choose to rely on word of mouth. Many satisfied clients will promote their trainer without a push from their trainer. Other clients may need their trainer to communicate with them that it would be helpful if the client told their friends, family, and co-workers about their services. Overall, it's advisable to wait until the client is satisfied with their progress and results before asking to be recommended.

Trainers who work in gyms, whether as a part of the gym's team or as an independent contractor, are walking advertisements for their business. Some trainers may choose to offer complimentary services to promote their work. Some gyms may market their trainers through their front desk services while other trainers may join a professional network that may include other healthcare providers and retailers. In a professional network, trainers will need to build relationships with others in the network so the other professionals can refer to the trainer and vice versa.

Finally, the last major method to generate leads is through the internet and social media. Having a significant presence on the internet, especially on social media, leads to opportunity. Producing content, such as videos, informative posts, blog posts, or whatever the trainer excels at making, will help grow their internet presence. It is paramount that all social media accounts and websites remain professional if they are used for personal trainer marketing.

Initial Contact

After a prospective client has taken interest in a trainer's services, it is important to move on to the initial contact, which then leads to the initial consultation. This can take the form of an in-person consultation, over the phone consultation, or an online consultation, which can be through video calls, emails, text, or any other digital communication method. Keep in mind, the initial contact and initial consultations can happen at different times or all at once. The trainer should be prepared for either situation.

The initial contact is an opportunity for the trainer to make a positive first impression and to gather important information. As mentioned previously, there are many factors to consider when making a positive first impression, such as body language, a warm greeting, and making sure the prospective client feels cared for. In the online environment, especially in text or email consultations or initial contacts, body language no longer matters but nonverbal communication skills are still important.

Active listening, or reading in text format, will still apply, especially using open and closed questions along with reflecting. Every trainer does this differently, but here are key points to keep in mind:

1. The trainer should discuss the client's fitness and health goals, physical limitations, and current experience and knowledge.
2. Trainers should have an application process for prospective clients to fill out so a trainer will have that information on file before the initial consultation or for future reference as appointments and programming go on.
3. Trainers must be aware of the limits of their scope of practice and refer to qualified professionals when appropriate.

Initial Consultation

The initial consultation comes after the initial contact, either immediately or as a follow-up appointment. The trainer should inform the client of when the consultation will be, what to wear and bring, and how much time the consultation will take. The initial consultation should take place in a relatively quiet area that allows for a reasonably private conversation.

If this is done online or over the phone, then it is less important to be secluded as long as it is confidential and communication is clear. After greeting the client warmly, the consultation begins with the trainer-client agreement. This is when expectations are established or re-established. This could include monetary consequences for no-shows or cancellations for both parties to receive, a refund policy, and everything in between.

The client must understand what is expected from them and what the client can expect from the trainer. The trainer will keep records of all of these agreements and a copy should be sent or given to the client.

First, the trainer needs to discuss health and medical history with the client. Intake forms should include medical/health history sections in addition to basic information and fitness goals. Additionally, clients with serious underlying conditions should obtain medical clearance from a doctor.

If the trainer concludes a medical clearance form is needed, training should not start until the form is filled, signed, and provided by the client so the trainer knows what a physician deems acceptable for the client's current state.

Informed consent is the next important step. From a legal, and ethical, standpoint, the client should know the potential risks and benefits of engaging in a guided exercise program. This provides the client an opportunity to understand what may or may not result from the training. Informed consent should be documented and the trainer and client should each have a copy.

Once all of the business, health, and legal information is documented and taken care of, the client's goals should be revisited. As mentioned earlier, the client's goals should have been discussed in the initial contact or put on the application form. The trainers should ask additional questions to clarify the client's input on their form or to add context to provided information. This is a chance for the trainer to paint a clear picture of what the client wants, can and cannot do, and what the client will need to learn.

Physical Assessment and Trial Session

After the goals have been revisited, a physical assessment and trial session is the next step. While the documentation provides the trainer with initial information, a physical assessment may reveal other limitations or places to improve, such as mobility restrictions, cardiorespiratory deconditioning, and muscular imbalances.

Each assessment should be clearly explained to the client and demonstrated so the client knows how to perform the assessment and the trainer will have accurate assessment information.

Some trainers may decide to offer a trial session. This session may be free or at a reduced cost. The trial session will take the client through a training session to get a preview of what they can expect when they sign up for training.

At the end of the trial session, the fitness professional should immediately attempt to make the sale. If the client declines or does not commit to training at that time, a follow-up should be performed within the next few days.

A well-executed initial interview using effective communication skills combined with a professional training experience during the trial session offers the best chance to close the sale and acquire a new client.

Follow Up

After both the initial consultation and the assessment/trial session, the trainer should follow up with the client by expressing appreciation for their time and effort.

A note, email, or call thanking the client for their time, expressing how good it is that they are taking a positive step in their health and fitness journey, and showing eagerness for the next session or training period will go a long way in keeping clients and reducing those who do not end up continuing their training with the trainer.

It is also helpful to remind the client of their next session and how to prepare for it. For online and in-person trainers, explaining what the next steps will look like will also be beneficial to keeping clients.

Closing the Sale

If all goes well, the client will communicate with the trainer after the trial period or the follow-up. At this point, it is time for the trainer to close the sale. Closing sales is a major topic in any business and is the bottom line when it comes to actually earning money as a personal trainer.

Every fitness professional develops their own methods for closing the sale. Ideally, by the time the potential client is sitting down with pricing in front of them, the fitness professional will have learned enough about the client and established enough rapport that the sale comes naturally.

If the client has made it this far into the process, they are likely going to make a purchase. Nevertheless, there are still objections that the client may bring up. Budget restrictions are one of the most common reasons a prospective client will cite when delaying making the final purchase.

It is certainly possible that the training sessions are entirely out of the person's budget. However, if they mention budget concerns, the professional can direct them to the most affordable option while also reminding them of the value it will have on their life to reach their fitness goals. This is a good time to reference any pertinent information from the initial interview.

It is important for the trainer to be professional and understanding when a client decides not to go further with the trainer. The trainer should thank the client for their time and recommend them to someone who might be more suitable.

If the client does choose to continue working with the trainer, the trainer should offer gratitude and enthusiasm to work with the client further.

For trainers who are independent contractors or work on their own, it is also important not to undersell their training. Underselling their training can lead to clients devaluing what the trainer is offering. The price for independent trainers will vary depending on what is being offered, location, and competition.

In the case of a client who has already decided they will be purchasing training sessions before the final discussion, closing the sale does not involve pitching specific packages or overcoming objections. In this case, closing is just a matter of agreeing on payment methods, scheduling the sessions, and collecting payment.

Summary

Communication skills are vital for every personal trainer to develop. Skills such as active listening and reflection help the client feel like they are being listened to when they talk to their trainer. Also, nonverbal communication such as body language can make or break the chance that a client will stick with that trainer.

Trainers need to be aware of verbal and nonverbal cues from their clients and themselves. The trainer who can marry communication skills with the sales process will have a strong opportunity to be successful.

The sales process includes being able to generate leads, conducting a successful initial consultation, providing a trial session if needed, following up with the client, closing the sale if the trainer can, or referring the client to a professional or resources that will better help them towards their goals.

Communication skills and a mastery of the sales process are key tools that all successful fitness professionals need to develop over time.

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Chapter 8

Applied Elements of Behavioral Coaching

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Introduction to Behavioral Coaching

It is no surprise that most Americans today do not exercise as recommended. According to the Center for Disease Control and Prevention, only 23.2% of Americans actually meet the recommended amount of aerobic and muscle-strengthening activity.[1] This is despite the fact that exercise has been proven to enhance sleep, increase energy, boost strength, manage weight, reduce stress and anxiety, and improve mood.[2]

Furthermore, having a regular exercise routine can help to manage and prevent diseases such as type 2 diabetes, high blood pressure, osteoporosis, arthritis, heart disease, and stroke.[2] While many folks would like to be active, it is often the habit formation and change in routine that can make it challenging to get started and stick with an exercise routine.

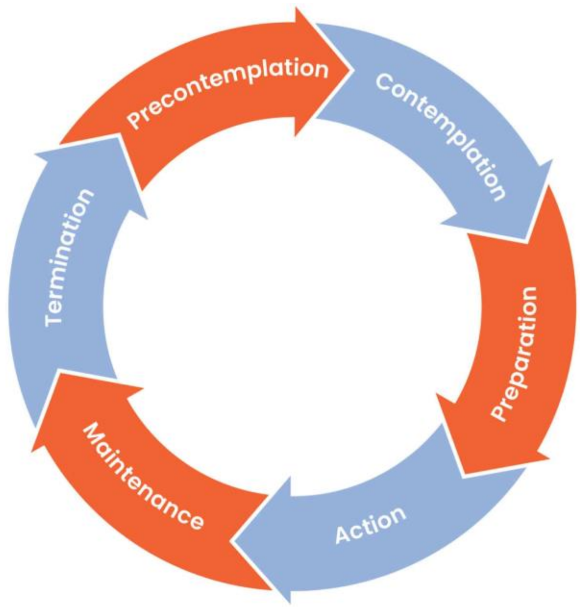
This is where knowledge around behavior change and habit formation can serve as a catalyst for exercise professionals to better support their clients. This chapter is specifically intended to explore how fitness professionals can work with their clients to understand where they are, and how they can work toward reaching their goals.

Some of the concepts and ideas that will be discussed include the transtheoretical model for stages of change, motivational interviewing, working through barriers, strategies to improve exercise adherence, social influences on exercise, and psychological benefits.

Stages of Change Model

There are five stages of change when looking at behavioral modification: precontemplation, contemplation, preparation, action, and maintenance. Relapse is also something to consider when thinking about the stages of behavior change and will be addressed in this chapter as well.

For the most effective behavioral change coaching, exercise professionals must meet clients where they are in their current stage and help them process through it as opposed to trying to force change. Ultimately, the client must feel empowered to pursue and maintain their fitness goals, and thoughtful behavioral coaching is one of the more reliable methods to achieve this state.



Precontemplation

People who are in this stage of change are not yet ready and have no desire to make a change. It is likely that they do not already have any exercise routine, and do not have intentions or thoughts around starting one within the next six months.

Individuals in this stage are unlikely to meet with a personal trainer. However, if someone in the precontemplation stage does happen to meet with an exercise professional, the best way to help them is to gently educate them around the benefits of exercise and steer them toward self-awareness.

Basic, easy-to-follow resources are the best type of educational material for clients in the precontemplation stage. In addition to educating clients, fitness professionals should inquire further with the client regarding their feelings about exercise. This type of conversation is also a good time to debunk any myths the client may have about exercise.

The following are a few questions that may be helpful to ask individuals in this stage:

- What comes up for you when you think about exercise?
- Are you open to talking about some of the benefits of exercise?
- What have you heard about exercise that stands out to you?

The fitness professional should never attempt to force the client to become interested or ready to begin exercising. The coach's primary roles during this stage of change are providing education through credible resources and fostering self-awareness.

Contemplation

Individuals in the contemplation stage are not exercising yet, but they are interested in getting started within the next six months. This stage gives fitness professionals a great opportunity to have a meaningful impact on the client's decision to move forward with their exercise routine. At this stage, the fitness professional must ask questions to get closer to understanding where the client's remaining ambivalence lies.

At the contemplation stage, the client typically has some level of motivation to exercise and likely understands the benefits of exercise to a certain extent. However, they still have some misunderstandings about what it means to be active or a continuing belief in one or more myths about exercise.

To best support people in the contemplation stage of change, the fitness professional must continue providing education. In this stage, individuals benefit from information and resources that support the positive thoughts they have around exercise and a gentle education that helps to redefine any misconceptions they may have.

The following are a few questions that may work well for clients in the contemplation stage of change:

- What do you see being a positive result of exercise?
- What seems to be a negative result of exercise?
- What do you already know about exercise?

Understanding where the client's ambivalence lies will inform the exercise professional's next steps. At that point, the exercise professional can provide education and credible resources, along with a positive attitude and motivating presence that keeps the client wanting to come back. Gaining this understanding will help the exercise professional to work with the client from the contemplation stage and into the preparation stages.

Preparation

People in the preparation stage of change are exercising but may not have a strong habit or plan established. At this point, they know the benefits of exercise and are motivated to work towards their fitness goals. People in this stage likely need some support in managing expectations and determining realistic goals.

The best way to support people in this stage varies based on the client's activity, however all support from the exercise professional should focus on the positive outcomes of exercising and help them to build self-efficacy within their exercise plan.

Strategies that are most helpful for people in the preparation stage include the following:

- Goal setting
- Affirming positive behaviors and thoughts about exercise
- Normalizing differences across exercise plans for individuals
- Tapping into previous positive experiences with establishing habits
- Discussing social support
- Generating awareness around potential barriers
- Encouraging a balance of exercise that supports the client's current capabilities

Action

People in the action stage are active and may have been active for a few weeks or months. They are engaging in a regular, healthy exercise habit, but have not yet reached the 6 month mark. It is important for the exercise professional to help clients in this stage to continue building on what is going well and recognize where there may be barriers or challenges.

The exercise professional can continue to educate clients about the benefits of exercise and build on what they already know and believe. Emphasizing the client's strengths to further grow that self-efficacy will keep clients feeling motivated and positive about their efforts.

Exercise professionals must learn to adjust the exercise program as needed during the action stage based on the client's barriers to exercise, as well as to ensure appropriate workout intensity. This requires an understanding of the client current's challenges on the part of the exercise professional.

Maintenance

At the maintenance stage, clients have been able to maintain their exercise habit for six months or more. They have likely figured out what works well most of the time, but still may slip into previous sedentary habits. Fitness professionals should continue to affirm the clients in this stage, give them regular kudos, and check in on their plans.

Goals can be set to last a bit longer than in previous stages and should be specific to what the client is experiencing at the present time, and what they expect down the line. The exercise professional can work on keeping the exercise programming in line with the clients' changing goals and plans, and should take progression into account.

How to Assess Stage of Change

Assessing a client's stage of change can be done through asking questions that will help to inform what and how much thought the client has or has not already put into their activity goals.

Below are some examples:

- How do you feel about exercise?
- What success have you had with reaching your activity goals?
- What has gotten in the way of exercise in the past? In the last 6 months?
- What has helped you to stick with activity goals so far in your experience?
- What have your best exercise routines looked like?
- By learning more about what the client is doing currently, or what they have done in the past, the exercise professional can think through which stage of change they are in currently.
- Is the client lacking interest in starting activity at all? They may be in the precontemplation stage.
- Is the client thinking about starting an exercise plan in the next several months? They may be in the contemplative stage.
- Is the client getting started and experimenting with exercise occasionally? They may be preparing to dive into their goals.
- Is the client already exercising regularly and working through challenges as they come up? This would be a client in the action stage.
- Has the client already been exercising for 6 months or more? This would be a client in the maintenance stage.

Motivational Interviewing

Motivational interviewing is a directive, client-centered counseling style for eliciting behavior change by helping clients to explore and resolve ambivalence.[3] With an understanding of the stages of change, motivational interviewing is the next key skill that coaches can use to elicit positive behavior change.

The following are the four main principles of motivational interviewing:

- Express Empathy
- Roll with Resistance
- Develop Discrepancy
- Supporting Self-Efficacy[4]

Expressing Empathy

Expressing empathy means relating to a client's experience wholly. This is done by validating their experience, and clearly communicating an understanding of that experience. This is an important skill to leverage when working with individuals who are feeling challenged.

For example, the client can benefit substantially when their coach helps them understand their experience is normal and help them stay positive and feel free from judgment.

Rolling with resistance is about avoiding direct head-on arguments and demonstrating to an individual that they have been heard. At this point, the exercise professional can promote the client's autonomy to make decisions about their goals versus what the exercise professional thinks is best.

The exercise professional should refrain from the 'righting reflex.' This is where the professional in a working relationship jumps in to offer a solution, advice, or suggestion to the client. While often made with good intentions, this advice or suggestion that is contrary to what the clients feels is best for them can create resistance against that advice or suggestion. This is natural human behavior. In this case, it would be more helpful to ask questions that allow the client to develop discrepancy.

Developing discrepancy is where the professional in the working relationship asks questions that allow the client to see how what they are saying or planning on does not necessarily align with their goals or values.

An example where this may come up would be a client sharing that they are motivated to continue with their exercise programming to achieve improved aerobic capability, but then they avoid incorporating aerobic activity in their exercise program. Developing discrepancy here would help the client see how they may be getting in their own way of reaching their goals.

Lastly, building on self-efficacy is where the professional supports the client in not only following through on their goals but also recognizing their own strengths and behaviors that allow them to do so. This can be done by leveraging affirmations and asking clients to reflect on what strengths they used to achieve their goals.

Active Listening

This is at the heart of motivational interviewing. Active listening lets the client know that their trainer or coach stays with them, tracking in the conversation, and curious to learn more. Using verbal cues such as "Hmm", "Yes", "Uh-huh" and "Ah" can be one way for a professional to show clients that they follow what the client shares, but to go beyond surface level will also include body language and building on the conversation.

Body language should mirror the client and maintain a welcoming presence. Some of the basics on body language would include not crossing arms or legs, maintaining appropriate eye contact, and head nodding. Next, is the exploration of building on the conversation by examining a few other key techniques.

Principles of Motivational Interviewing

1

Express empathy

Accomplished through validating the client's experience and communicating an understanding of that experience.

2

Roll with resistance

Accomplished by encouraging client autonomy in decision making and asking questions that assist the client in making their own best decisions.

3

Develop discrepancy

Accomplished by asking questions that help the client discover incongruencies between their stated goals and their current behaviors.

4

Support self-efficacy

Accomplished by leveraging affirmations and reflections from the client about their own ability to achieve their stated goals.

Building Rapport with OARS

This is an acronym for Open Ended Questions, Affirmations, Reflections, and Summaries. Using these four techniques reassures the client that their trainer is fully present.

Open Ended Questions

Open ended questions are inquiries that go beyond ‘yes’ or ‘no’ answers. These questions should require the client to think through their responses. Generally, open ended questions begin with ‘what’, ‘where’, and ‘how.’ Take note that questions beginning with ‘why’ are not included here.

Questions that begin with ‘why’ can make the recipient of the question feel as though they are being judged, so are very important to avoid in a trainer-client relationship. The open ended questions used in conversations with clients should build off of what the client has already been sharing.

Affirmations

Statements of what the client is doing well and what behaviors or strengths they are exhibiting will help to bolster their self-efficacy. These statements should go beyond a simple ‘Good job’ and should really encompass specific language about what the client did. For example, “You accomplished your goal of 4 workouts last week! You’re dedicated.”

Reflections

Reflections are statements reiterating what the client is telling the exercise professional in a way that shows the client their trainer interprets their words. Reflections help the client see that their coach actively listens to them and comprehends what they are saying. This goes beyond regurgitating the client’s words.

For example, in response to their client saying “I just want to feel like I am strong again. I haven’t been able to stay consistent for a long time,” their coach might respond with, “you’re ready to feel like yourself again.”

Summaries

This technique can be used to move the conversation forward while letting the client know that their exercise professional tracks what the client is saying. Summaries differ from reflections in that they simply summarize what the client tells the trainer. This is in contrast to a reflection, where the trainer shares their interpretation of what the client is saying.

Summaries help clients to feel heard and are an important step to keep conversations moving forward while demonstrating active listening.

Overcoming Common Barriers to Exercise

At some point during a client's time adhering to their exercise program, they are going to run into barriers or other challenges that make it difficult to move forward. Overcoming these obstacles will be much easier if the trainer and client address some of the common barriers to starting and adhering to exercise plans.

Time

Lack of time is the most common barrier to participating in exercise.[5] As the exercise professional, it can be meaningful to support the client in discovering some awareness around this perceived barrier to achieving goals. Inquiring around the client's schedule and self-reflection tend to lack the level of detail needed for gaining this type of self-awareness.

People often are not unaware of how much time is spent on social media, browsing the web, or even watching TV. To help clients to gain a higher level of awareness around where their time is being spent, the exercise professional may have them do a 'time audit.'

This would request that the client takes note of how they are spending their time for a designated period, such as a week. Doing this is meant to help the client to have a clear picture of how they are currently spending their time and may help them to see where they have room to add in a new routine.

Unrealistic Expectations or Goals

Many clients starting out with a new trainer do not have recent experience with an exercise routine. With the best of intentions and eagerness to grow, they may tend to set goals for themselves that are not quite realistic, helpful, or even safe. When set appropriately, goals should help clients to build confidence, self-efficacy, and motivation.

Goals should be challenging enough to keep clients interested and inspired, but realistic enough that they are attainable. It is key for the exercise professional to work with clients to understand why this is important, and how to apply the concept.

Lack of Confidence

For those who are just getting started with exercise, or who have not engaged in an exercise routine in a gym setting, it is common to lack confidence around getting active, and the ability to get active.[6]

For clients who are lacking confidence, the exercise professional may work with these clients to start with exercise routines that are within their comfort zone to start, such as a walking program. Once the client starts reaching their 'starter goals', they will start to gain confidence and feel more comfortable moving forward. This can take some time, and the exercise professional can support the process by continuing to affirm the client's strengths and behaviors.

Strategies to Improve Exercise Adherence

Once clients get started with their goals, it will become about working with them to adhere to the exercise programming. In addition to having discussions about their barriers, the exercise professional can be proactive about bolstering adherence.

SMART Goal Setting

Working with clients to establish their goals comes up time and time again. At this point, it's best to discuss how to start the conversation and what tenets are needed for a meaningful goal.

There is a handy acronym that is used in the behavior change world that makes it easy to remember the 5 components of a meaningful goal: SMART. These goals should be Specific, Measurable, Attainable, Relevant, and Time Based.

Kicking off the goal setting conversation will start off with the big picture, and then will move to a more granular and specific plan. To start things off and to really understand what is motivating the client to start an exercise program, the following questions can guide the client to think through what their outcome goals are:

- What would success look like 6 months from now?
- What would you like to have achieved one year from now?
- What is your ultimate goal for your exercise program?
- What would you like to be different as a result of your exercise program?

- Once the client has shared more about the direction they'd like to go, and what is important for their success with an exercise program, it will be time to get more specific and determine action steps.

Specific

Goals should include details that indicate exactly what the action is going to be. This means the client should be given the opportunity to think through what exactly it is they are looking to achieve or do via the goal that is being set.

For example, "Going to the gym" is not very specific for an exercise goal, unless the goal is simply to get to the gym. To make this more specific, it may look like this: "Riding the stationary bike and completing a strength training routine."

Measurable

This component should make it easy to know whether the goal has been achieved or not. There should be some sort of measurable value indicated within the goal, i.e. how many times per week, an increasing cadence, or a certain amount of time.

To build on the goal that was stated above, this may look like: "Riding the stationary bike for 30 minutes and completing strength training routine 3 times per week."

Attainable

As mentioned previously, goals should always be attainable for the client. This means the goal should take into consideration where the client is at currently, and what is achievable for them to continue to grow. For example, it would not be realistic for someone who hasn't been running to set a goal to run a marathon in a month. What may be realistic in this example would be a 5k in 4-6 weeks.

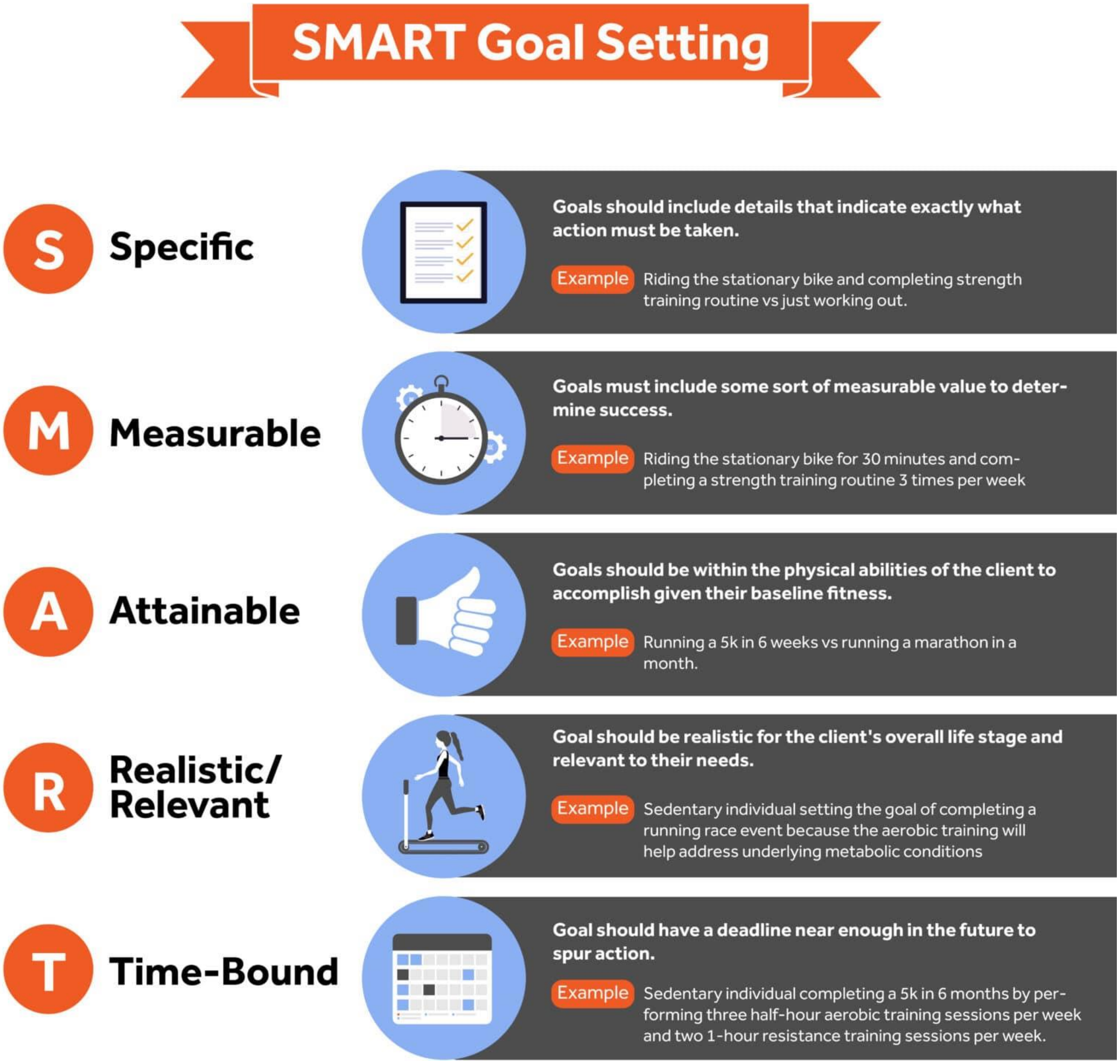
Relevant

Goals should always be co-created between the client and exercise professional, with the client's outcome goals in mind. The SMART goal should be related and relevant to what the client is looking to achieve. For example, if a client is looking to run a marathon, their SMART goal should be centered around running, with cross training that supports the sport.

Time-Based

To ensure the client's tasks are being prioritized and they are maintaining motivation, it is important to put a realistic, yet ambitious end date for the goal. For example, to build on the marathon goal, if a client wants to run a marathon next year, they may set a goal for the present time that has them reaching a 10 mile run within 4 months.

Setting goals that are as close to SMART as possible will help clients to really think through what it will look like for them to follow through on their goals. This will lead to improved adherence.



Self-Monitoring and Tracking

Self-monitoring or tracking are strategies that can help clients to not only see their progress over time but can also add a layer of self-accountability to their routine. Once a client starts writing down or tracking what they are doing for exercise, they will start to build more self-efficacy. This creates a record of the success that they are seeing so far. There are several different ways a client may track: websites, apps, journals, etc.

Manage Expectations

Clients may come to the exercise professional with visions of how they will go from being inactive to fully integrating exercise into their everyday life. It is important to work toward managing appropriate expectations for the process of establishing an exercise habit.

Discuss with them the length of time it will take to start seeing progress, normalize barriers and roadblocks, bring awareness to the importance of consistency, and connect the dots between where the client is currently and where they'd like to be.

Support

Having the support of an exercise professional, friends, families, or colleagues can be really meaningful to clients. They may look to an individual 'gym buddy,' or a family member who keeps them accountable to their goals.

Whatever the support looks like, it will likely come into play time and time again throughout the client's journey.

A social network can have a profound influence on a client's physical activity behaviors.[7] There are a number of different types of support systems that can help a client's success with their exercise programming.

Having a positive presence and influence in their corner will add to their feelings of belonging within the exercise community, provide a level of accountability, and help to build motivation.

Types of Support

Instrumental

This is the service-like or required type of support that makes a client's success possible. An example of this type of support would be a client's spouse watching the kids twice per week so the client can attend an aerobics class.

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Emotional

This support provides a sense of love or care for the client. It is likely to be coming from close friends or family who may lend an ear, provide validation, and encourage.

Informational

This support mechanism involves when the client looks for information, advice, and facts. It is likely that the exercise professional is providing this type of support to clients.

Companionship

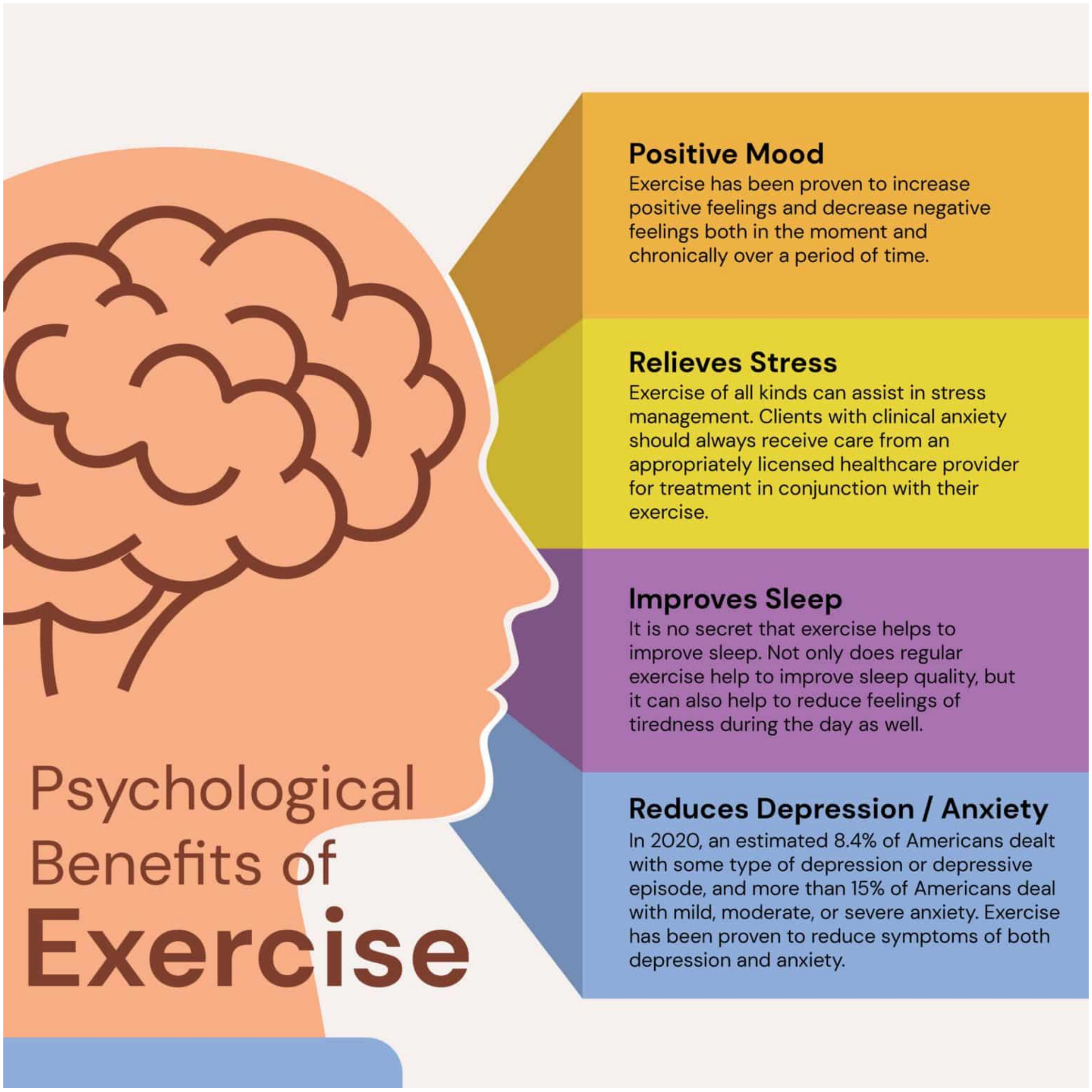
This type of support brings a sense of community or belonging. Clients may have a friend that they attend an exercise class with, or who they meet at the gym for workouts regularly. Some of the social support systems that are common in the exercise world include family or friends, exercise leaders, and exercise groups. Family or friends can offer up emotional or instrumental support where they help the client to feel a sense of hope or inspiration to continue going.

Friends or family may also be instrumental supporters in that they are the ones who make it possible for the client to move forward with their goals: taking responsibility off the client's plate, financial support to join a gym or class, or driving the client to or from their workouts.

Exercise leaders would be social connections that have a high level of exercise experience, knowledge, or engagement. This may be someone that the client knows already, or it could be the exercise professional working with them to come up with an exercise program.

Finally, exercise groups can be really impactful in creating community and companionship for clients. This may be through an exercise class, a meet-up group, or some other type of exercise community that bolsters support in a group setting.

Psychological Benefits of Exercise



Exercise provides psychological benefits through a variety of biological mechanisms. The following are some of the top examples of well-researched benefits of exercise when it comes to mental health and psychology.

Positive Mood

Exercise has been proven to increase positive feelings or mood and decrease negative feelings.[8] This occurs both in the moment and holds up over a period of time.

Relieves Stress

Exercise of all kinds can be a catalyst for stress management.[9] Whether a positive or negative stressor, finding ways that work well for each individual to manage stress is an important skill. While exercise can be a component of a stress management plan, if there is a clinical issue related to a client's stress, they should be referred to an appropriate clinician.

Improves Sleep

It is no secret that exercise helps to improve sleep. Not only does regular exercise help to improve sleep quality, but it can also help to reduce feelings of tiredness during the day as well.[2]

Reduces Depression / Anxiety

In 2020, an estimated 8.4% of Americans dealt with some type of depression or depressive episode, and more than 15% of Americans deal with mild, moderate, or severe anxiety.[11, 12] Exercise has been proven to reduce symptoms in both depression and anxiety.[13]

Summary

Despite the many benefits of exercise, many individuals do not reach the minimum recommended requirements for weekly activity, so it may be up to the fitness professional to determine where in the state of change model their clients are and how to move them along it.

They can first build rapport with the client using OARS, deal with overcoming barriers to exercise, and set SMART goals which help organize expectations into measurable outcomes. All these steps act as psychological tools that can be useful in moving sedentary clients towards an active lifestyle, or they can even help clients who do not currently feel motivated in their fitness pursuits.

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Chapter 9

Health History and Anthropometric Assessments

Introduction

Comprehensive client assessments encompass a variety of subjective and objective assessments used to determine a client's risk factors, goals, and current physiological measurements to establish a baseline.

The overall resting assessment sequence is as follows:

1. Medical history form including lifestyle questionnaire and PAR-Q
2. Resting heart rate
3. Resting blood pressure
4. Bodyweight
5. Height
6. Circumference measurements
7. Skinfold measurements

While all clients must fill out the medical history and related forms prior to engaging in physical activity under the trainer's supervision, the specific additional assessments will vary depending on client goals and health history, comfort with the assessments, and the availability of equipment.

A comprehensive fitness assessment provides subjective and objective information including any risk factors relevant to training, resting physiologic measurements, and anthropometric measurements such as height, weight, and skinfold measurements that allow for objective progress tracking.[1, 2]

As a general rule for safety, coaches must advocate that their client see their primary physician prior to beginning or increasing the intensity of an existing exercise program if needed. However, clients who select "yes" to any of the questions on the Physical Activity Readiness Questionnaire (PAR-Q) must obtain medical clearance prior to the trainer beginning an exercise program.[1,2]

Medical History Questionnaire

A preparticipation health screening includes a medical history, lifestyle questionnaire, and Physical Activity Readiness Questionnaire (PAR-Q). Often, these forms are combined into a single intake form, but they can be separate as well.

Medical history forms should gather the following information:

- Current medications, especially for metabolic conditions
- Injury history
- Cardiovascular risk assessment via the PAR-Q

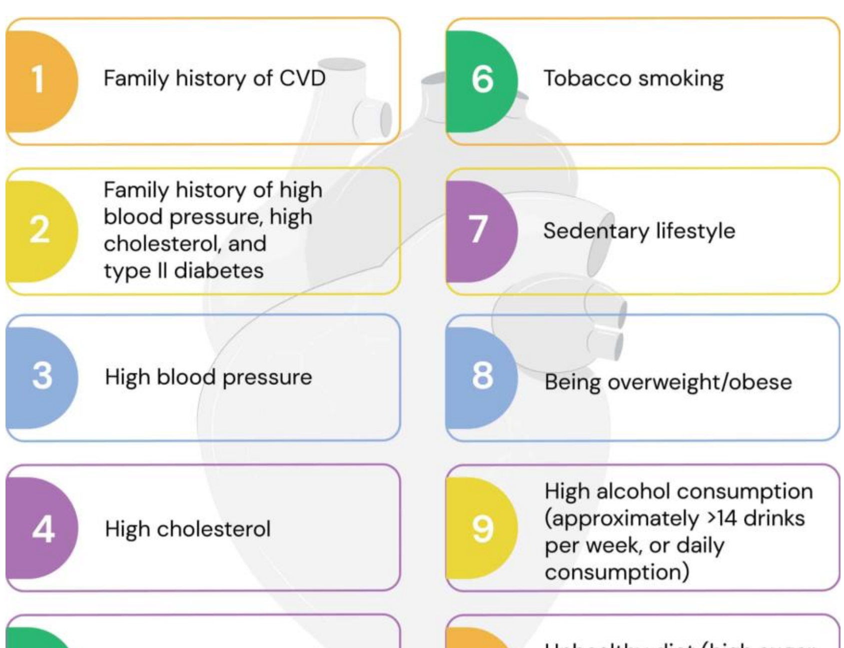
The main pre-existing screen is offered by the Physical Activity Readiness Questionnaire (PAR-Q) and includes some variation of the following questions:

1. Has your doctor ever said that you have a heart condition or high blood pressure?
2. Do you feel pain in your chest at rest or when performing physical activity?
3. Do you lose your balance because of dizziness or do you ever lose consciousness?
4. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?
5. Are you currently taking prescribed medications for a chronic medical condition?
6. Do you have a bone, joint, or soft tissue problem that could be made worse by a change in your physical activity?
7. Has a doctor ever said that you should only do medically supervised physical activity?

Cardiovascular Disease Risk Factors

In addition to the PAR-Q form, intake forms should also assess cardiovascular risk factors. Based on the number of risk factors, fitness professionals can make generalized decisions about safe, optimal programming.

Additionally, a client with multiple risk factors should also get medical clearance from a qualified healthcare professional prior to beginning any exercise program. The following are the risk factors for cardiovascular disease (CVD) to consider on top on the PAR-Q questionnaire responses:



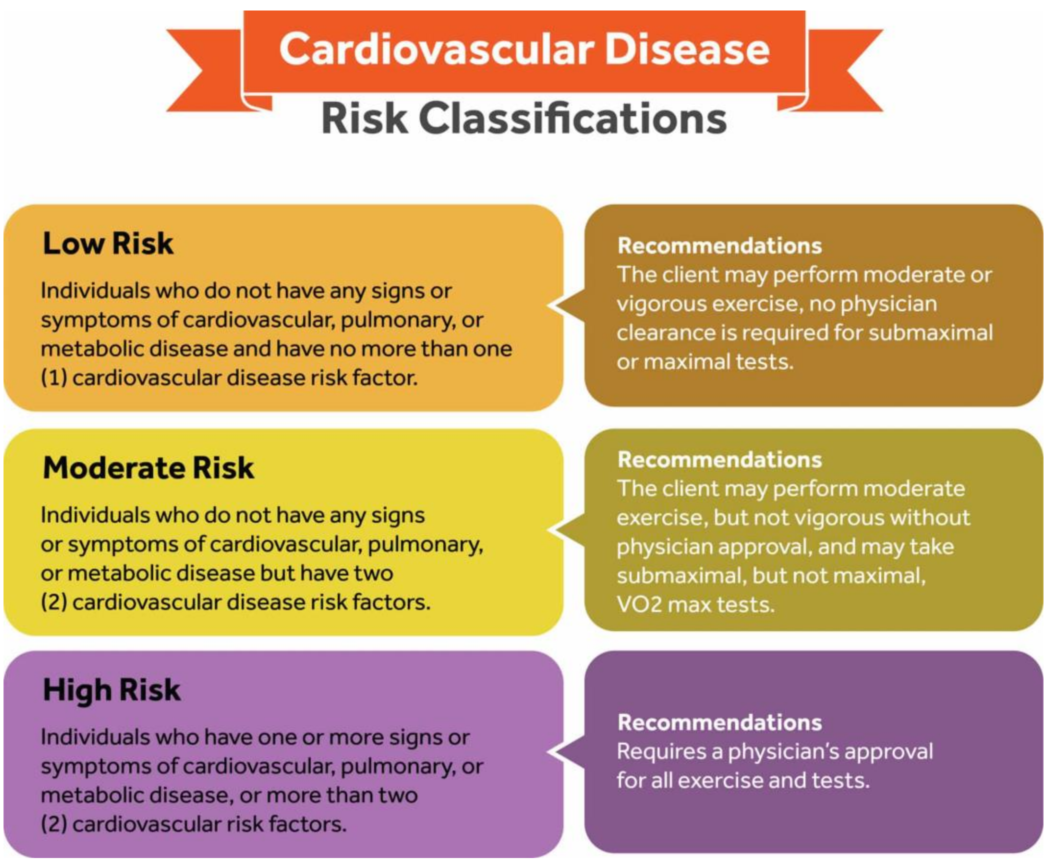
Risk Factor Assessment

The following stratification can be used to generalize about risk factors and make appropriate recommendations:

- **Low Risk:** individuals who do not have any signs or symptoms of cardiovascular, pulmonary, or metabolic disease and have no more than 1 cardiovascular disease risk factor.
- **Moderate Risk:** individuals who do not have any signs or symptoms of cardiovascular, pulmonary, or metabolic disease but have 2 cardiovascular disease risk factors.
- **High Risk:** individuals who have one or more signs or symptoms of cardiovascular, pulmonary, or metabolic disease**,** or more than 2 cardiovascular risk factors

Recommendations Based on Risk Levels

- **Low Risk:** client may perform moderate or vigorous exercise and no physician is needed for submaximal or maximal tests
- **Moderate Risk:** client may perform moderate exercise but not vigorous without physician approval, and may take a submaximal, but not maximal, VO_2 test
- **High Risk:** requires a physician's approval for all exercise and tests



Lifestyle Factors for Injury Risks

Collecting information about a client's profession and recreational activities helps personal trainers determine common movement patterns, as well as typical energy expenditure levels during the course of an average day.

This kind of information helps personal trainers begin to recognize imperative signs about the client's musculoskeletal structure and function, potential health and physical limitations, and boundaries that could affect the safety and value of an exercise program. For example:

- Extended periods of sitting could contribute to muscular imbalances, prolonged periods of low energy expenditure throughout the day, and potentially poor cardiorespiratory conditioning.
- Repetitive movements can cause musculoskeletal injury and dysfunction. Also, these can create pattern overload in muscles and joints, which may lead to tissue trauma and eventually kinetic chain dysfunction, especially in jobs that require a lot of overhead work or awkward positions such as construction or painting.[4, 16]

Physiological Assessments

Resting Heart Rate (RHR)

RHR is influenced by factors such as fitness status, fatigue, body composition, drugs/medication, alcohol, caffeine, and stress.[1, 7, 10]

The assessment of RHR is an indicator of a client's overall cardiorespiratory health as well as fitness status. RHR is a good indication of overall cardiorespiratory fitness, whereas exercise HR is a strong gauge of how a client's cardiorespiratory system responds and adapts to exercise.

Resting Rate Classifications

- Sinus bradycardia: slow HR, anything less than 60 beats per minute.
- Normal sinus rhythm: 60-100bpm.
- Sinus tachycardia: fast heart rate, which is greater than 100bpm.

Heart rate is either easily recorded at either the base of the wrist (radial), or against the side of the trachea (carotid). To gather an accurate recording, it is best to teach clients how to record their resting HR on rising in the morning. Clients can test their RHR three mornings in a row and average the three readings.

Resting Heart Rate Procedure

1. Locate anatomic site
2. Gently press down with two fingers over palpation site
3. Count the number of pulsations for a specific time period (6, 10, 30 or 60 sec)
4. Begin counting the first pulsation as 0 when the timing is initiated simultaneously or, if a lag time occurs after the start time, begin with the number 1
5. Calculate beats per minute via multiplication based on the time interval
6. 6 second count – multiply by 10
7. 10 second count – multiply by 6
8. 30 second count – multiply by 2

Blood Pressure (BP)

Blood pressure is defined as the outward force exerted by the blood on the vessel walls.

It is measured using an aneroid sphygmomanometer, which consists of an inflatable cuff, a pressure dial, a bulb with a valve, and a stethoscope When assessing BP, it is imperative to use calibrated equipment that meets certification standards and to follow standardized protocol.

Systolic blood pressure (SBP) is the pressure created by the heart as it pumps blood into circulation via ventricular contraction. Diastolic blood pressure (DBP) represents the pressure that is exerted on the artery walls as blood remains in the arteries during the filling phase of the cardiac cycle, or between beats when the heart relaxes.[6, 18]

To determine systolic pressure, listen for the first observation of the pulse. Diastolic pressure is determined when the pulse fades away.

Blood Pressure Classifications

- Normal: 120/80 mmHg
- Prehypertension 120-139/ 80-89
- Hypertension Stage 1: 140-159 / 90-99
- Hypertension Stage 2: above 160 / above 100

Resting Blood Pressure Measurement Procedure

1. Position yourself to hear the BP and see the manometer scale.
2. Make sure the stethoscope is flat and placed completely over the client's brachial artery.

3. Client should be seated, with feet flat, legs uncrossed, and the arm free of any clothing and relaxed. The arm and back should be well supported by furniture.
4. Center the bladder of the BP cuff over the client's brachial artery.
5. Position the client's arm so it is slightly flexed at the elbow.
6. Firmly place the bell of the stethoscope over the artery located in the antecubital fossa.
7. Inflate the cuff to approximately 20 mm Hg above the SBP, if known.
    a. Up to 140-180 mm Hg for a resting BP
    b. Up to 30 mm Hg above disappearance of the radial pulse
8. Deflate the cuff slowly 2 -3 mm Hg per heartbeat by opening the air exhaust valve on the hand bulb.
9. Record measures of SBP and DBP in even numbers rounding up.
10. Rapidly deflate the cuff to zero after the DBP is obtained.
11. Wait for 1 full minute before repeating the BP measurement.

Blood Pressure Classifications

Classification	Blood Pressure
Normal	120/80
Prehypertension	120-139/ 80-89
Hypertension Stage 1	140-159 / 90-99
Hypertension Stage 2	>160 / >100

Body Composition Testing

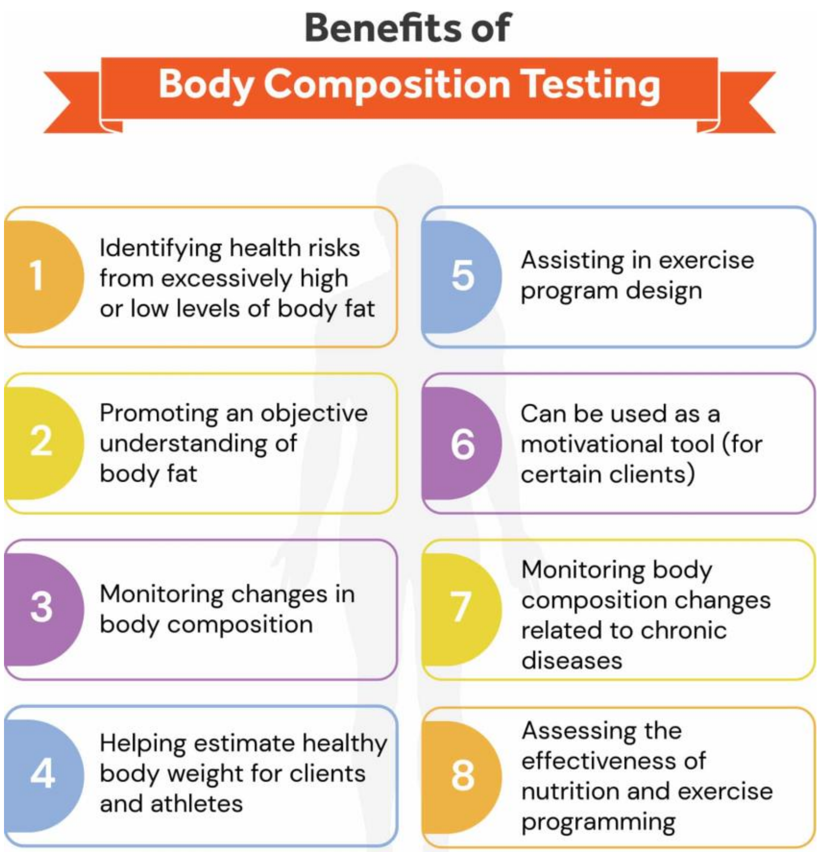
There are many methods to assess body composition. Each of these methods gives the trainer insight in determining the best course of action for a fitness program.

Body composition refers to the relative percentage of body weight that is fat versus fat-free tissue, more commonly reported as “body fat percentage.”

Fat-free mass can be defined as total body weight excluding stored fat, including muscle, bones, water, connective and organ tissues, and teeth, whereas fat mass includes essential fat (vital for normal body functions such as neural pathways and hormones) and nonessential fat (storage fat or adipose tissue).[13, 16]

Body composition testing can:

- Identify client’s health risk for excessively high or low levels of body fat
- Promote client’s understanding of body fat
- Monitor changes in body composition
- Help estimate healthy body weight for clients and athletes
- Assist in exercise program design
- Be used as a motivational tool (for certain clients)
- Monitor changes in the body composition that are associated with chronic diseases
- Assess the effectiveness of nutrition and exercise programming



In order to obtain correct calculations, technology has provided many different brands of equipment with different procedures, calculations, and modes of use. The various modes of obtaining results of body composition include:[1, 2, 14]

- Skinfold measurement: uses a caliper to estimate the amount of subcutaneous fat beneath the skin.
- Bioelectrical Impedance: uses a portable instrument to conduct an electrical current through the body to estimate fat. This is based on the hypothesis that tissues that are high in water content conduct electrical currents with less resistance than those with little water (such as adipose tissue)
- Underwater weighing: often referred to as hydrostatic weighing, has been the most common technique used in exercise physiology labs to determine body composition.
- Air displacement Plethysmography (ADP): the "bod pod" is an egg-shaped chamber that measures the amount of air that is displaced when a person sits in the machine. Two valves are needed to determine body fat: air displacement and body weight. ADP has a high accuracy rate but the equipment is expensive.
- Dual-energy x-ray absorptiometry (DEXA): Ranks among the most accurate and precise methods. DEXA is a whole-body scanning system that delivers a low-dose x-ray that reads bone and soft-tissue mass. DEXA has the ability to identify regional body-fat distribution.
- Magnetic resonance imaging (MRI): uses magnetic fields to assess how much fat a person has and where it is deposited. Since MRIs are located in clinical settings, using an MRI solely for calculation of body fat is not practical.
- Near-infrared interactance (NIR): uses a fiber optic probe connected to a digital analyzer that indirectly measures tissues composition (fat and water). Typically, the biceps are the assessment site. Calculations are then plugged into an equation that includes height, weight, frame size, and level of activity. This method is relatively inexpensive and fast, but generally not as accurate as other techniques.
- Total body electrical conductivity (TOBEC): uses an electromagnetic force field to assess relative body fat. Much like the MRI, it is impractical and too expensive for the fitness setting.

In order to begin body composition testing and related calculations, the following information is needed: height, weight, and circumferences of selected areas.

Body Mass Index (BMI)

Body Mass Index (BMI) is one of the commonly used calculations that delineates weight categories based on

BMI = body mass (kg) divided by the height squared (m^2) = (kg / m^2).

The major shortcoming of BMI is that it does not differentiate body fat from fat-free weight and has only a modest correlation with body fat percentage measured via hydrostatic weighing.

Waist-to-Hip Ratio

Waist-to-hip ratio is a comparison between the circumference of the waist and the circumference of the hip. This ratio reflects the relative distribution of body fat, which correlates to multiple metabolic risk factors.

Individuals with more weight or circumference on the waist are at higher risk of hypertension, type 2 diabetes, hyperlipidemia, and coronary artery disease than individuals who are of equal weight but have more of their weight distributed on the extremities.[1, 2, 4]

With the help of formulas and calculations, the Skinfold test with the use of calipers is still used on individuals who are under 30% body fat and under the care of an experienced personal trainer.

Skinfold Measurements

Skinfold measurements are a more precise way to estimate body fat percentages without expensive equipment. Skinfold measurements are most reliable on individuals who are under 30 percent body fat.

Skinfold measurements are taken via handheld calipers and then entered into one of several formulas depending on which measurements are taken.

While skinfold measurements can be fairly reliable, it takes substantial practice under qualified supervision to consistently take accurate, reliable measurements.

Skinfold Measurement Sites

- Abdominal: vertical fold; 2 cm to the right side of the umbilicus
- Triceps: vertical fold; on the posterior midline of the upper arm, halfway between the acromion and olecranon processes, with the arm held freely to the side of the body
- Biceps: vertical fold; on the anterior aspect of the arm over the belly of the biceps muscle, 1 cm above the level used to mark the triceps site
- Chest/Pectoral: diagonal fold; one-half the distance between the anterior axillary line and the nipple (men), or one-third of the distance between the anterior axillary line and the nipple (women)
- Medial calf: vertical fold; at the maximum circumference of the calf on the midline on the midline of its medial border

- Midaxillary: vertical fold; on the midaxillary line at the level of the xiphoid process of the sternum. An alternate method is a horizontal fold taken at the level of the xiphoid/sternal border on the midaxillary line
- Scapular: diagonal fold (45-degree angle); 1-2 cm below the inferior angle of the scapula
- Suprailiac: diagonal fold; in line with the natural angle of the iliac crest taken in the anterior axillary line immediately superior to the iliac crest
- Thigh: vertical fold; on the anterior midline of the thigh, midway between the proximal border of the patella and the inguinal crease (hip)[14]

Procedures

1. All measurements should be made on the right side of the body with the subject standing upright.
2. Caliper should be placed directly on the skin surface, 1 cm away from the thumb and finger, perpendicular to the skinfold, and halfway between the crest and the base of the fold.
3. Pinch should be maintained while reading the caliper.
4. Wait 1-2 sec before reading caliper.
5. Take duplicate measures at each site and retest if duplicate measurements are not within 1-2mm.
6. Rotate through measurement sites or allow time for skin to regain normal texture and thickness.[14]

Summary

Health history, resting, and anthropometric assessments for all new clients are important for multiple reasons. Health history and PAR-Q is vital to obtain to ensure the client is physically capable of safely participating in exercise.

Resting assessments further flag risk factors and give a baseline for cardiorespiratory fitness prior to any performance testing.

Finally, anthropometric assessments give quantitative data about the client's body composition, which further assists in designing optimal exercise programs and also allows objective measurement of progress.

While the specific assessments will vary depending on the individual client and training environment, all clients must complete the health history and PAR-Q before beginning any exercise under trainer supervision.

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Chapter 10

Posture, Movement, and Performance Assessments

John Lindala, MS

Introduction

Posture and movement assessments are crucial steps fitness professionals must use to determine any muscle imbalances or movement issues that should be focused on or corrected during the exercise program.

In the field of personal training, movement assessments are utilized as a baseline tool to determine injury risk, establish a range of motion patterns, and identify movement dysfunctions in a potential client.[1]

Ideally, the movement assessments used for a particular client directly relate to the actions the client will regularly engage in (squats, push up, etc.), thus providing the most objective indicators of performance possible.[2]

Biomechanical Checkpoints

Key points to focus on are around the major joints and will be specific to each assessment. The primary focal point for the lower body will be the hip complex and, for the upper body, the shoulder complex. The less mobile joints (knee, elbow, etc.) play a secondary role for most assessments but still deserve full attention.

Observers should denote asymmetry throughout the range of motion of each assessment. As the client performs each assessment, they should be viewed from a frontal, lateral, and posterior position to get a full picture of the client's kinematic chain.

Denote obvious compensation patterns as a guide for how to build a program to maximally benefit the client.

The use of static postural assessment helps to identify muscle imbalances, range of motion difficulties, and flexibility limitations. A static postural assessment provides excellent indicators of problem areas that can then be further evaluated so that the trainer can then come up with an action plan.

Static Postural Assessment

This provides a basis for developing an exercise strategy to target contributing factors of incorrect movement patterns and neuromuscular inefficiency. This information might provide knowledge for which selection of stabilization exercises and stretching and self-myofascial release strategies might be used.

There are three common distortion patterns:

1. **Pronation distortion syndrome:** characterized by foot pronation (flat feet) and adducted and internally rotated knees (knock knees).

    Lower crossed syndrome: characterized by an anterior tilt to the pelvis (arched lower back).

    Upper crossed syndrome: characterized by a forward head and rounded shoulders.[19, 20]

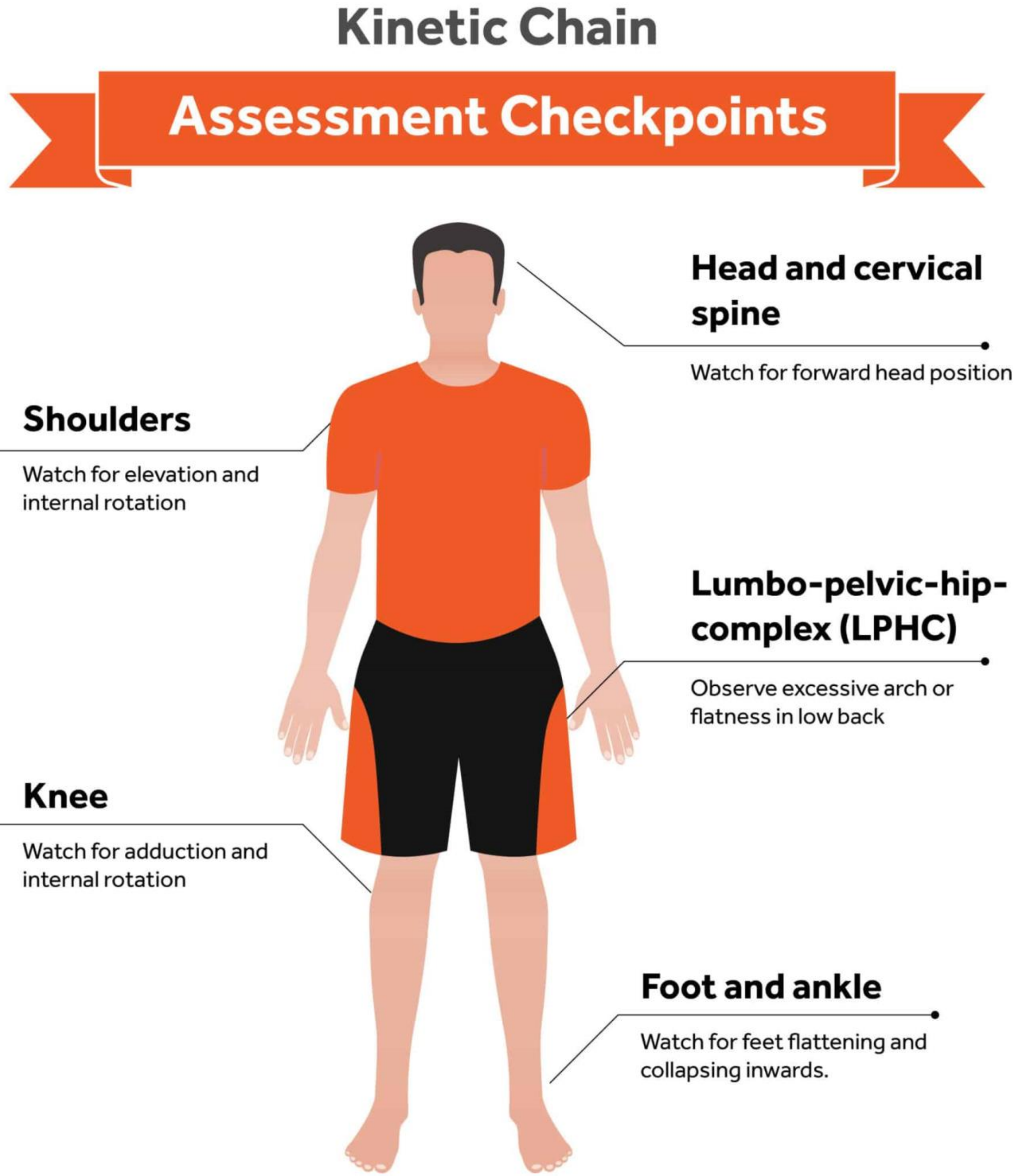
Postural assessments require observation of the kinetic chain, consisting of:

1. Foot and ankle
2. Knee
3. Lumbo-pelvic-hip-complex (LPHC)
4. Shoulders
5. Head and cervical spine

A static posture assessment may offer valuable insight into:

Muscle imbalance at a joint and the working relationships of muscles around a joint.

Altered neural action of the muscles moving and controlling the joint – tight or shortened muscles are often overactive and dominate movement at the joint, potentially disrupting healthy joint mechanics.


Kinetic Chain
Assessment Checkpoints
Head and cervical spine
Watch for forward head position
Shoulders
Watch for elevation and internal rotation
Lumbo-pelvic-hip-complex (LPHC)
Observe excessive arch or flatness in low back
Knee
Watch for adduction and internal rotation
Foot and ankle
Watch for feet flattening and collapsing inwards.

Overhead Squat Assessment

General Purpose

The squat assessment is a dynamic movement assessment designed to measure the client's functional range of motion. It helps determine overall core strength, balance, kinesthetic awareness, and movement pattern discrepancies.[3]

Procedure

Have the client start standing with feet comfortably spaced shoulder width apart and toes straight ahead. Demonstrate a proper squat while instructing the client to perform the move to the best of their ability.

Have the client perform 10 squats while watching the movement pattern. If performing the overhead squat, instruct the client to fully extend arms overhead before beginning the squat and keep them there throughout the movement. A PVC pipe may also be held overhead with a wide grip if available. During the squats, the trainer can move to slightly different angles if necessary to determine more information about the movement pattern.

Movement Findings

1. **Compensation:** Feet turn out. Throughout the squat movement the client's feet rotate out.

    Indications: Overactive soleus, lateral gastrocnemius, and biceps femoris. Underactive medial gastrocnemius, semimembranosus, semitendinosus, gracilis, and sartorius.

2. **Compensation:** Knees cave in. Knee visibly points or tracks inward during the squat rep. Typically, knees will be seen caving in on the eccentric phase and will circle medially with the start of the concentric phase of the squat.

    Indication: Overactive adductor, biceps femoris, tensor fascia latae, and vastus lateralis to the dominant side. Target strengthening for the gluteus medius, gluteus maximus, and vastus medialis oblique.

3. **Compensation:** Torso falls forward. Client cannot maintain a neutral spine and their torso flexes forward towards the floor.

   Indication: Overactive soleus, gastrocnemius, rectus femoris, psoas, rectus abdominis. Underactive anterior tibialis, gluteus maximus, and erector spinae.

4. **Compensation:** Low back arches. Hyperextension of the low back during squat.

   Indication: Overactive rectus femoris, psoas, erector spinae, latissimus dorsi. Underactive gluteus maximus, hamstrings, lower core musculature.

5. **Compensation:** Arms fall forward (overhead). Arms fail to stay vertical and fall towards the floor.

   Indication: Overactive latissimus dorsi, teres major, and pectoralis group. Underactive mid/lower trapezius, rhomboids, and rotator cuff.

6. **Compensation:** Head protrudes forward. Head fails to stay stacked in a neutral position.

   Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive deep cervical flexors.

Single Leg Squat Assessment

General Purpose

The single leg squat assessment is designed to measure lumbo-pelvic hip stability of the client.[4]

Procedure

Have the client start standing with feet together. They will pick up one foot to a height of 45 degrees of hip flexion while keeping that foot off the ground during the squat. Arms should be straight out in front of the client with the hands clasped together.

Instruct the client to squat on the standing leg as low as comfortable or to 60 degrees of knee flexion. Instructor should be able to assess the range of motion within 3 to 5 repetitions then have the client repeat the test on the opposite leg.

Movement Findings

1. **Compensation**: Knees cave in. Knee visibly points or tracks inward during the squat rep. Typically, the knee will be seen caving in on the eccentric phase and circling medially with the start of the concentric phase of the squat.

   Indication: Overactive adductor, biceps femoris, tensor fascia latae, and vastus lateralis to the dominant side. Target strengthening for the gluteus medius, gluteus maximus, and vastus medialis oblique.

Lunge Assessment

General Purpose

The lunge assessment measures movement asymmetries, lateral stability, and balance.[5]

Procedure

Position the client into the lunge by having them take one stride forward while leaving their back foot planted on the ground. With their arms crossed over their chest, have the client attempt to touch their back knee to the ground bending both knees to 90 degrees. Perform 5 repetitions on the same leg before switching sides.

Movement Findings Including Tight & Weak Patterns

1. **Compensation:** Asymmetrical weight shift: client noticeably shifts weight further to one side.

   Indication: Potential side dominance with similar indications as the knee caving in on a squat assessment. Overactive adductor, biceps femoris, tensor fascia latae, and vastus lateralis to the dominant side. Target strengthening for the gluteus medius, gluteus maximus, and vastus medialis oblique.

2. **Compensation:** Excessive knee bend: knee of forward leg drives forward into deep knee flexion as a sign of quadriceps dominance.

   Indication: Overactive quadriceps and hip flexor complex. Underactive gluteal and hamstring groups.

3. **Compensation:** Lack of hip extension: posterior hip doesn't move into extension and stays flexed.

    Indication: Overactive psoas and rectus abdominis. Underactive gluteus maximus and lower core stabilizers.

Step Up Assessment

General Purpose

The step-up assessment measures the strength and stability of the gluteus maximus, hamstrings, and quadriceps as well as the client's balance.

Procedure

Find a stable and elevated surface for the client to step up onto and have the client stand directly in front of the surface. Arms should be crossed in front of their chest. Instruct them to place one foot on the surface and step up into full extension of the planted leg. Opposite leg should be pulled into hip flexion to 90 degrees. Perform 5 repetitions on the same leg before switching sides.

Movement Findings Including Tight & Weak Patterns

1. **Compensation:** Hip dropping upon lifting of foot.

    Indication: Overactive psoas, rectus femoris, and tensor fascia latae. Underactive gluteus maximus/medius, quadratus lumborum, and transverse abdominis.

2. **Compensation:** Inability to dorsiflex foot. Client cannot lift toes up.

    Indication: Overactive gastrocnemius and soleus. Underactive anterior tibialis.

3. **Compensation:** Forward lean into step. Client leans forward over leg to step up.

    Indication: Lack of strength through the range of motion.

4. **Compensation:** Failure to flex hip. Client cannot get into 90 degrees of hip flexion.

    Indication: Overactive gluteus maximus and hamstring group. Underactive psoas, rectus femoris, tensor fascia latae, and rectus abdominis.

Pulling Assessment

General Purpose

Designed to test the strength and range of motion of the posterior shoulder girdle, specifically the muscles acting on the scapula.[6]

Procedure

Submaximal assessment in which the instructor will need access to a cable row, suspension trainer, or resistance band. From a standing or seated position, have the client start with arms extended and holding resistance in a neutral grip. Torso should begin and remain upright throughout the assessment. Instruct client to pull handles to their torso as far as they can comfortably. Instructor should be able to assess client within 5-10 repetitions.

Movement Findings Including Tight & Weak Patterns

1. **Compensation:** Low back arches.

    Indication: Overactive psoas and rectus abdominis. Underactive lower core stabilizers.

2. **Compensation:** Shoulders elevate. With concentric motion shoulders elevate rather than remaining neutral.

    Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive middle/lower trapezius.

3. **Compensation:** Head protrudes forward. Head fails to stay stacked in a neutral position.

    Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive deep cervical flexors.

4. **Compensation:** Shoulder rounding forward: shoulder complex fails to stay inline and rotates forward during pull.

    Indication: Overactive upper trapezius, levator scapulae, and pectoralis major/minor. Underactive middle/lower trapezius, rhomboids, and rotator cuff.

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    Indication: Overactive upper trapezius, levator scapulae, and pectoralis major/minor. Underactive middle/lower trapezius, rhomboids, and rotator cuff.

Pushing Assessment

General Purpose

Designed to test the range of motion for the anterior shoulder girdle and chest.[7]

Procedure

Submaximal assessment in which the instructor will need access to a cable machine, resistance bands, or a suspension trainer. Can be performed from a standing or seated position. Have the client start with an upright torso and resistance handles at chest height with arms wide and elbows bent to 90 degrees. Perform the test by having the client fully extend arms until both handles are directly in front of the client's chest and shoulder. Instructor should be able to assess the client within 5-10 repetitions.

Movement Findings Including Tight & Weak Patterns

1. **Compensation:** Low back arches.

   Indication: Overactive psoas and rectus abdominis. Underactive lower core stabilizers.

2. **Compensation:** Shoulders elevate. With concentric motion shoulders elevate rather than remaining neutral.

   Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive middle/lower trapezius.

3. **Compensation:** Head protrudes forward. Head fails to stay stacked in a neutral position.

   Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive deep cervical flexors.

Overhead Pressing Assessment

General Purpose

The overhead pressing assessment measures range of motion of the upper body, strength of the elbow, extensors strength of the medial shoulder, and core stability.[8]

Procedure

Submaximal assessment in which the instructor will need access to a bar. Client starts in either a seated or standing position. Bar will be brought to shoulder height with hands just outside of shoulder width apart. Goal for the assessment is to monitor range of motion while the client extends the bar fully overhead and returns to the starting position.

Movement Findings Including Tight & Weak Patterns

1. **Compensation:** Asymmetrical weight shift: weight is clearly shifted towards one arm.

   Indication: Side dominance and potential lack of strength in non-dominant limb.

2. **Compensation:** Shoulders elevate. With concentric motion shoulders elevate rather than remaining neutral.

   Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive middle/lower trapezius.

3. **Compensation:** Head protrudes forward. Head fails to stay stacked in a neutral position.

   Indication: Overactive upper trapezius, sternocleidomastoid, and levator scapulae. Underactive deep cervical flexors.

4. **Compensation:** Bar fails to remain vertical and deviates forward into sagittal plane (sagittal deviation).

   Indication: Overactive latissimus dorsi, teres major, and pectoralis group. Underactive mid/lower trapezius, rhomboids, and rotator cuff.

Performance Assessments

While movement assessments determine the quality of movement capabilities of a client, performance assessments determine strengths and weaknesses of the client.

Performance assessments require clients to directly display their skill in a particular subset (agility, strength, endurance, etc.) of fitness.

Push Up Test

General Purpose

To test the strength endurance upper body pushing capabilities of a client.[9]

Procedure

Test can be performed either from toes or knees depending on client's preference and background. Contraindications include shoulder, elbow, or wrist injury. If any exist, a modified test may be performed where the movement only goes to 90 degrees of elbow flexion.

If no contraindications exist, have the client start in the push up position of their choice. Instruct them that a proper rep involves controlled lowering of the torso until they touch their chest to the floor then return to full extension of the elbows.

Count all continuous repetitions until the client can no longer perform the movement.

Davies Test

General Purpose

The Davies test measures the client's upper body agility and stabilization.[11]

Procedure

To set up the test, put two pieces of tape or floor marker 36 inches apart on the floor. Have the client start in a push up position with one hand on each piece of tape. Set a timer for 15 seconds and explain to the client to bring their left hand to meet their right and back, then their right hand to meet their left and back.

Continue alternating hand movements during the duration of the 15 second timer. Count every hand movement back and forth as one repetition. Repeat the test 3 times and take the average score.

Trial	Time	Score
1	15 sec	
2	15 sec	
3	15 sec	

Shark Skill Test

General Purpose

The Shark Skill test assesses lower body agility and stability.

Procedure

Create a 3×3 grid on the floor consisting of 9 squares measuring 12” in on all sides. Have the client start standing in the center square on one foot. In a designed pattern they will jump to a particular square then return to the center square. They will continue around the grid until all squares have been touched and then return to the center square.

Let them practice one round with each foot. After practicing, they will perform two rounds per leg for time alternating legs each round. For each mistake they make, add 10 seconds to their round time.

Trial	Time	Mistake Tally	Penalty Time (#Mistakes x .1)	Total Time (Time + Penalty Time)
Practice Right				
Practice Left				
#1 Right				
#1 Left				
#2 Right				
#2 Left				

General 1 Rep Max Procedures

General Purpose

The 1 repetition max test is designed to measure absolute strength in one specific motion. It can be performed through a variety of exercises with the same general construct.

Procedure

Ideally the test will be performed utilizing free weights with the trainer functioning as a spotter with the option for additional help if necessary.

1. Have the client do a warmup set of 8-10 repetitions at 50-60% of perceived maximum.
2. After allowing a 1-minute rest (longer can be taken if needed), have the client perform a set of 3-5 repetitions at 60-80% of perceived maximum.
3. Next the first 1 repetition maximum attempt is performed. Add weight based on the client's perceived maximum and performance then attempt the first lift.
4. If successful, allow the client to rest 3-5 minutes before adding more weight and performing a second attempt.
5. Repeat until the client fails a lift or has clearly reached a maximum.
6. Ideally a successful 1 repetition maximum test is completed within 3 attempts.

Vertical Jump Assessment

General Purpose

The Vertical Jump Assessment determines a client's maximal vertical jump power.

Procedure

Test utilizes either a large-unobstructed wall or vertical jump testing device. Have the client first stand next to the measuring surface with feet flat and arm nearest surface fully extended overhead. Measure the maximal beginning reach. Then demonstrate a proper jump with arm swing.

Lower body quickly into a partial squat while extending arms behind torso then rapidly extend entire body vertically into a jump and touching measuring surface at the apex of the jump.

Measure the difference between standing and jumping heights. Allow client 3 attempts to gain maximal height with a short rest between each.

Lower Extremity Functional Test (LEFT)

General Purpose

The lower extremity functional test (LEFT) is used as a measure of an athlete's ability to return to sport. During the test the athlete will be required to perform every movement pattern that may occur in sport.

Procedure

A diamond grid is created with four cones, where the vertical cones are placed 30 feet apart. The trainer place two horizontal cones 10 feet apart halfway between the vertical cones to create the diamond pattern. Client will then run the following patterns in a continuous motion test. (Cones labeled A, B, C, D.A is the start, so moving clockwise B would be 15 feet ahead and 5 to the left, C would be 30 feet ahead of A, and D would be 15 feet ahead and 5 to the right.)

1. Forward sprint A-C-A
2. Backpedal A-C-A
3. Side shuffle right leg first A-D-C-B-A
4. Side shuffle left leg first A-B-C-D-A
5. Karaoke right leg first A-D-C-B-A
6. Karaoke left leg first A-B-C-D-A
7. Forward run figure 8's circling C cone from left to right A-D-C-B-A
8. Forward run figure 8's circling C cone from right to left A-B-C-D-A
9. 45-degree cuts A-D-C-B-A
10. 45-degree cuts A-B-C-D-A
11. 90-degree cuts (outside leg) A-D-B-A
12. 90-degree cuts (outside leg) A-B-D-A
13. 90-degree cuts (inside leg) A-D-B-A
14. 90-degree cuts (inside leg) A-B-D-A
15. Backpedal A-C-A

16. Forward Sprint A-C-A

40-Yard Dash

General Purpose

Designed to test a client's explosive lower body power and maximum movement velocity.

Procedure

This is best if performed on a track, but any level surface will work. Measure a 40-yard space clearly marked with start and finish lines. Instruct the client on how to position themselves at the start line. Typical positions include a track stance with one hand on the ground or a standing start, whichever chosen should best reflect performance needs of the client.

Instructor stands at the finish line with a stopwatch to ensure accurate timing. Instruct the client to begin when ready. When the client moves, begin the watch and stop when they cross the finish line. Take the best effort of 2-3 attempts.

Yo-Yo Intermittent Recovery Test

General Purpose

The Yo-Yo intermittent recovery test assesses a client's ability to repeatedly perform intervals over a long period of time. Additionally, it can be used to determine a client's VO2 max.[11]

Procedure

Instructor will need a flat, non-slip surface, marking cones, measuring tape, recording sheet, and a pre recorded copy of the test and beep. The cones are layed out in 3 lines that are 20 meters and 5 meters apart respectively. The client starts at the middle line. When prompted by the recorded beep they will run to the 20-meter line. Another beep will prompt the client to return to the starting line.

Each round the recorded beeps speed up, lowering the amount of time the client has to complete a shuttle. There is a 10 second active recovery between shuttles where the client must walk or jog around the first line 5 meters away and return to the starting line.

The first time a client fails to complete a shuttle they are given a warning. The second failure leads to the test being completed. An alternative version exists titled the Yo-Yo intermittent endurance test wherein the active recovery time is lowered to 5 seconds.

To estimate VO2 max use the following formulas:

Intermittent Recovery Test (IR1 aerobic):

Yo-Yo IR1 test: VO2max (ml/min/kg) = IR1 distance (m) × 0.0084 + 36.4

Intermittent Endurance Test (IR2 anaerobic):

Yo-Yo IR2 test: VO2max (ml/min/kg) = IR2 distance (m) × 0.0136 + 45.3

1-Mile Run

General Purpose

The 1-mile run is designed to test a client's aerobic endurance capacity.

Procedure

Ideally performed on a track without interruption of the run or walk/run effort. The goal of the test is to have the client complete one mile as fast as they possibly can. Shorter versions can be introduced for younger children (1/4 mile) and pre-teens (1/2 mile).

20-Yard Shuttle Test

General Purpose

The 20-yard shuttle test (also known as the 5-10-5) is used to test a client's agility, explosiveness, overall body control and speed.

Procedure

Three cones are placed in a line 5 yards apart from each other. The client starts at the middle cone. First, the client sprints to the right cone (5 yards), then all the way to the far left cone (10 yards), and back to pass the middle cone (5 yards).

The instructor begins timing at the start and stop time when the client runs past the middle cone.

Two different variations exist in which the client must touch each cone or simply place their foot in line with the cone before changing directions. Allow the client sufficient time to rest then have them repeat the test starting in the opposite direction.

Kneeling Chest Launch Test

General Purpose

The kneeling chest launch test is designed to measure a client's upper body coordination, power, and strength.

Procedure

Instructor needs a 2 or 3 kg medicine ball, measuring tape, soft pad to kneel on, and an open area. The client begins on both knees with an upright torso. Toes should be pointed behind the client to keep the client from utilizing extra traction from the lower body.

Client starts by holding the ball with both hands directly overhead. Then they lower the ball to their chest as they sit back towards their heels. In one smooth motion, the client then explodes up and throws the ball in a pressing motion for maximum distance. Knees should remain on the ground for the throw, but the client is allowed to fall in front of the starting line upon release.

The client shouldn't favor one arm over the other in the throw and their spine should not rotate. Allow the client a practice throw to determine best practice and aim for maximal distance. To test, allow the client two throws with at least a minute of rest between attempts.

Pull Up Test

General Purpose

The pull up test is used to measure upper body strength and endurance.

Procedure

This test is performed to the failure of good form. The instructor needs access to a high-horizontal pull up bar tall enough so that when the client hangs from the bar at full extension, their feet cannot touch the ground.

Begin by having the client grasp the bar in either an overhand or underhand grip. Grip width will vary by client but will be approximately shoulder width. Once ready, the client raises body until their chin clears the top of the pull up bar.

Then, they lower themselves back to full arm extension and repeat until technical failure. The motion should be smooth without additional bending, kicking, or swinging of the body.

Summary

Assessments are useful tools for fitness professionals in the field of personal training. Static postural assessments give important information to the trainer about which common distortion pattern a client may be experiencing, movement assessments indicate range of motion and muscle asymmetries that should be corrected, and performance tests give the personal trainer an idea of the client's fitness in a particular area.

Each test should be used for a particular purpose to answer specific questions that need to be answered to keep the client healthy and moving toward their fitness goals.

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Chapter 11

Cardiorespiratory Fitness Assessments

John Lindala, MS

Introduction

Fitness professionals routinely assess the cardiorespiratory fitness level of clients. Cardiorespiratory fitness assessments include submaximal and maximal exercise tests designed to provide baseline information and progress measurements throughout the duration of the training program.

Cardiorespiratory fitness is the maximal capacity of the body's circulatory and respiratory systems to provide oxygenated blood to the muscles during physical activity.[1] It is vital to prolong good health and optimize activities of daily living. Studies have shown a pronounced effect from the role of cardiorespiratory fitness in chronic disease prevention and as a result, it should be a priority in any fitness regimen.[1, 2]

Properly gauging cardiorespiratory fitness can be accomplished through a battery of tests with data readily available to compare results based on age, gender, and potentially body weight. The key measurables for most tests include heart rate and breathing rate to determine maximal oxygen uptake or VO_2 max.[2]

The VO_2 max is the maximum amount of oxygen the body can utilize during intense exercise, measured in milliliters of oxygen used per kilogram of body weight per minute (ml/kg/min). Overall, a correct assessment of VO_2 max is the gold standard in terms of measuring aerobic fitness.

Assessment Sequencing

When determining the optimal sequencing of assessments, the National Strength and Conditioning Association recommends the following:

1. Resting measures such as heart rate, body composition, and blood pressure.
2. Agility tests
3. Maximal power and strength tests
4. Muscular endurance tests
5. Fatiguing Anaerobic tests
6. Aerobic tests

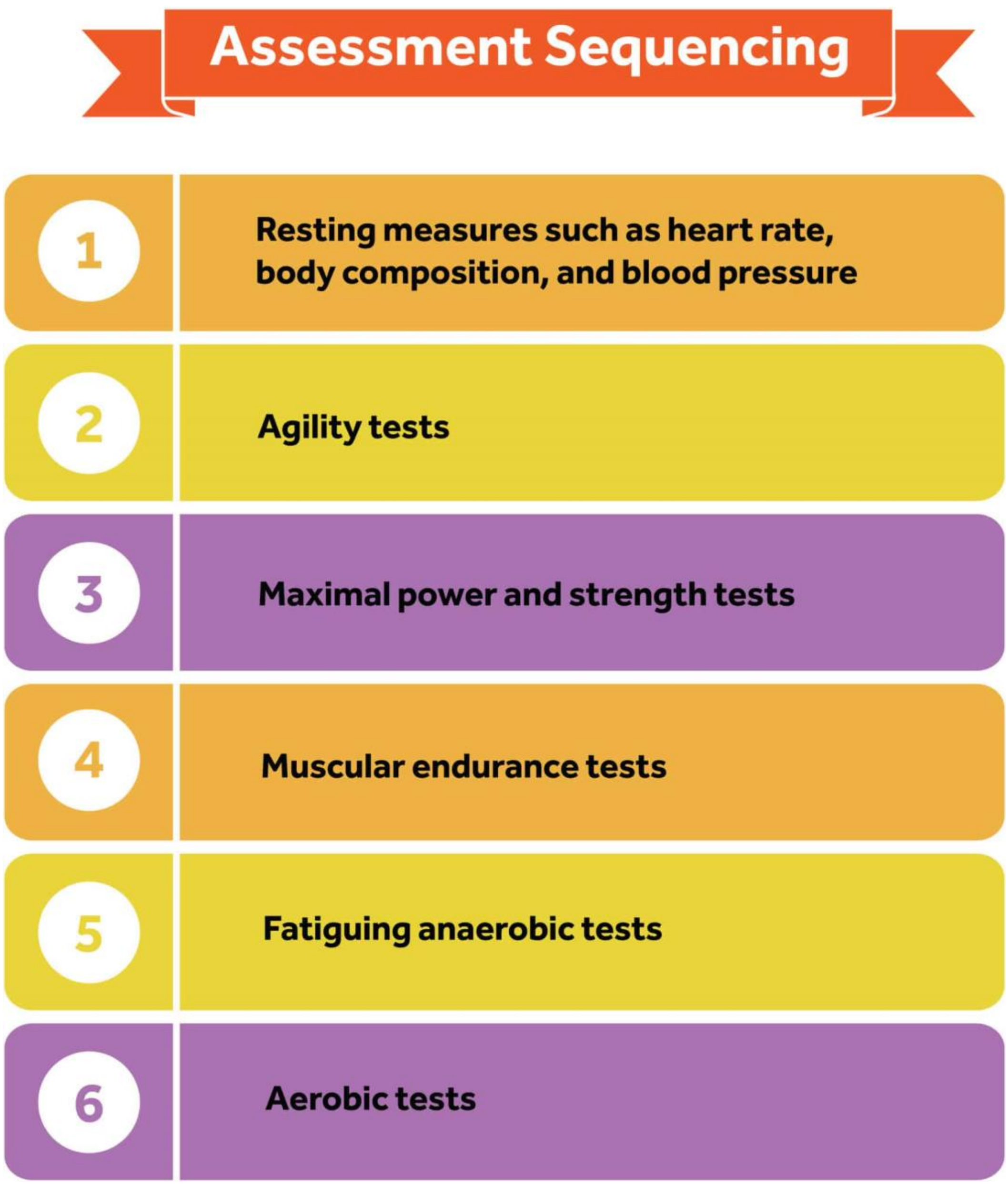
The reasoning behind this sequence is based on exercise fatigue and recovery along the energy metabolism pathway. The earlier tests fatigue the fast-acting metabolic pathways and require a short rest period to be replenished.

As the assessments begin taxing the glycolytic pathways, recovery requirements grow to several minutes between tests. The aerobic tests tax the oxidative metabolic pathway and may take up to 24 hours to fully recover.

This sequencing of tests based on energy metabolism is designed to optimize performance throughout every stage of testing.[3]

Optimal test sequencing yields the most accurate results; however, fitness professionals should know that some flexibility exists when sequencing these assessments depending on the needs of the participant, the timing involved, and access to equipment.

Test selection for determining cardiorespiratory fitness depends on the overall status of the participant and the availability of specific modalities, as some may prove to be cost-prohibitive or hard to access.



Selecting Appropriate Assessments

Test selection for determining cardiorespiratory fitness will equate to the overall status of the participant and the availability of specific modalities as some may prove to be cost prohibitive or hard to access.

The relationship between heart rate and oxygen uptake is mostly linear. As a result, relatively accurate estimates of VO2 max can be made employing submaximal testing and ventilatory thresholds.[4,5,6] Usage of submaximal testing, as opposed to maximal testing, is more user friendly and greatly reduces the risk of injury or harm to the user. Specifically, when thinking of untrained or sedentary individuals, the risk associated with maximal VO2 testing far outweighs the benefit when a submaximal test can provide a solid estimate.

Submaximal testing can be under predictive of VO2 scores when working with highly trained and athletic participants.[7] Therefore, maximal testing is recommended for athletic and well-trained populations.[4]

Protocols for Select Cardiorespiratory Fitness Assessments

VO2 Max Testing

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Submaximal testing often underpredicts VO_2 scores when working with highly trained and athletic participants.[7] Therefore, maximal testing is recommended for athletic and well-trained populations.[4]

YMCA 3-Minute Step Test

Purpose: Sub-maximal VO_2 max test

Equipment: 12-inch step, stopwatch, metronome, and optional heart rate monitor

Metronome should be set to 96 beats per minute.

Notes:

- Allow the participant to practice stepping to the beat of the metronome.
- After completion of the 3 minutes, the participant sits down immediately onto the bench and remains still.
- The score of the test is the participants' one-minute post-test heart rate.
- Compare the score to the YMCA step test published chart.

A full cycle of 4 beeps equals one complete step. The participant should perform 24 steps per minute.

Procedure:

7. Demonstrate the alternating step cadence to be performed.
8. Step one foot up onto the bench with the first beat.
9. Step the second foot up with the second beat.
10. Step one foot down onto the floor with the third beat.
11. Step the second foot onto the floor with the fourth beat.
12. Tester starts counting heart rate manually within 5 seconds of completion of test.
13. Continue counting heart rate for one full minute post-test.
14. If using a heart rate monitor, take the heart rate 1-minute post exercise. This is the "score" used for calculations.
15. Compare the score to the YMCA step test published chart.

YMCA 3-MINUTE STEP TEST TABLE

Ratings for Men by Age	18-25	26-35	36-45	46-55	56-65	≥65
Excellent	50-76	51-76	49-76	56-82	60-77	59-81
Good	79-84	79-85	80-88	87-93	86-94	87-92
Above average	88-93	88-94	92-88	95-101	97-100	94-102
Average	95-100	96-102	100-105	103-111	103-109	104-110
Below Average	102-107	104-110	108-113	113-119	111-117	114-118
Poor	111-119	114-121	116-124	121-126	119-128	121-126
Very poor	124-157	126-161	130-163	131-159	131-154	130-151
Ratings for Women by Age	**18-25**	**26-35**	**36-45**	**46-55**	**56-65**	**≥65**
Excellent	52-81	58-80	51-84	63–91	60-92	70-92
Good	85-93	85-92	89-96	95-101	97-103	96-101
Above average	96-102	95-101	100-104	104-110	106-111	104-111
Average	104-110	104-110	107-112	113-118	113-118	116-121
Below Average	113-120	113-119	115-120	120-124	119-127	123-126
Poor	122-131	122-129	124-132	126-132	129-135	128-133
Very poor	135-169	134-171	137-169	137-171	141-174	135-155

1-Mile Run Test

Purpose: Aerobic fitness assessment and VO_2 max estimator.

Equipment: Stopwatch, 1.5 mile (2.4 km) flat and hard running course.

Procedure

1. Have the participant complete a proper warmup prior to the start of the test.
2. The goal is to complete the course distance in a run as quickly as possible.
3. Have the participant line up on the starting point and at the testers "go" they will begin running.
4. Walking is allowed, if necessary, but the goal remains to finish as fast as possible.
5. Have the participant perform a cool-down walk following the completion of the test.
6. Calculate the participant's VO_2 max using the formula:

For males:

$$VO_2 \text{ max} = 91.736 - (0.1656 \text{ x body mass in kg}) - (2.767 \text{ x time in minutes})$$

For females:

$$VO_2 \text{ max} = 88.020 - (0.1656\text{x body mass in kg}) - (2.767\text{x time in minutes})$$

Note: time should be converted to a decimal (9 minutes and 30 seconds = 9.5).

12-Minute Run/Walk

Purpose: The 12-minute run/walk test is an easily performed test used to measure aerobic fitness and estimate a participant's VO_2 max. It is the maximum distance a participant can travel in 12 minutes.

Equipment: Level track, stopwatch, cones for marking distance, or a treadmill set to 1% incline if a running track is not available.

Procedure:

1. Have the participant complete a proper warm up prior to the start of the test.
2. The goal of the test is to complete the maximum possible distance in 12 minutes at either a run or a walk depending on the participant's ability level.
3. When the participant is ready, have them start, optional to the participant if time is read out during the test.
4. Have a cone or other marker ready when time is running out and immediately mark the participant's position or notate their distance traveled when the 12-minute timer completes.

Notate the distance traveled in either kilometers or miles then calculate the VO2 max using one of the formulas below:

Kilometers: VO_2 max = (22.351 x kilometers) – 11.288

Miles: VO_2 max = (35.97 x miles) – 11.29

Compare the participant's results to readily available online charts with standardizations for age and gender.

Astrand-Rhyming Cycle Ergometer Test

Purpose: The Astrand-Rhyming cycle ergometer test is a submaximal aerobic fitness test. The Astrand test uses heart rate and estimated percentage of maximal aerobic capacity to calculate VO_2 max.

Equipment: Cycle ergometer, stopwatch, heart rate monitor, or optional ECG monitor.

Procedure:

1. Have the participant warm-up on the cycle ergometer for 2 to 3 minutes at a cadence of 50 with no resistance.
2. The goal of the test is for the participant to achieve steady state heart rate over a 6-minute period of cycling.
3. Ideal heart rate range will fall between 125 and 170 beats per minute.

Initial workload for men and women will fall in the ranges of:

- Unconditioned men- 300-600 kg-m/min
- Conditioned men- 600-900 kg-m/min
- Unconditioned women- 300-450 kg-m/min
- Conditioned women- 450-600 kg-m/min

Note: If needing to convert from watts to kg-m/min multiply the watts by 6.12.

Record the participant's heart rate every minute during the test.

If the heart rate is not within 5 beats of each other at minutes 5 and 6 continue for an additional minute.

If the steady state heart rate is not between 125 and 170 beats per minute, adjust the workload accordingly and repeat the 6-minute period.

Calculate the participant's VO2 max utilizing the "workload" in kg-m/min, and heart rate steady state "HRss."

- Females VO2max = (0.00193 x workload + 0.326) / (0.769 x HRss – 56.1) x 100
- Males VO2max = (0.00212 x workload + 0.299) / (0.769 x HRss – 48.5) x 100

Ventilatory Threshold Testing

Ventilatory threshold testing is based on the linear relationship of oxygen and carbon dioxide during breathing (ventilation). With the onset of exercise, ventilation will match the cellular demand for oxygen by the body meaning the body will use more oxygen. Initially the body will increase tidal volume pulling in more oxygen per breath while breathing rate remains relatively the same.

When exercise nears maximal intensity, breathing rate disproportionally increases compared to oxygen intake. This increased breathing rate aids in releasing the increased production of carbon dioxide as a byproduct of switching to anaerobic glycolysis as a primary ATP source.[6, 8]

Two points to consider with ventilatory threshold hold testing are the first ventilatory threshold point (VT1) or “crossover point” and the second ventilatory threshold point (VT2) or “compensation point.”

VT1 is the point at which blood lactate starts accumulating faster than it can be cleared by the body. This point represents the moment oxygen demands on the body outpace the oxygen delivery capabilities and lactate buildup begins.[6]

VT2 represents hyperventilation and the point at which the increased breathing rate can no longer disperse the carbon dioxide at that rate.

The VT2 can otherwise be described as the onset of blood lactate accumulation.[8]

- Relative performance intensity of VT1 corresponds to the highest pace someone can sustain for 1 to 2 hours.
- VT2 represents the maximal sustainable pace for 30 to 60 seconds.

Talk Test

Purpose: The purpose of the VT Talk Test is to establish VT1 and the associated heart rate of the VT1 threshold.

During the test, intensity should be increased incrementally. The purpose of the test is to find VT1, and if large changes in intensity are made, the exerciser may unintentionally pass VT1, invalidating the test. As such, the talk test is best performed using machines with adjustable intensities to allow precise increases in exercise intensity.

Appropriate increases in intensity include an additional .5 mph, 1% grade, or 15 watts.

With each level increase, the heart rate steady state should also increase by approximately 5 beats per minute.

Level increases usually happen every 60-120 seconds depending on when the heart rate steady state is reached. Ideally, the test can be completed within 8 to 16 minutes overall.

During each level of the test, the exerciser reads or repeats a phrase. Preconstructed cue cards with long complete sentences can be read off or the exerciser can recite a phrase from memory such as the Pledge of Allegiance.

When the exerciser reaches an intensity where they are unable to string together 5-10 words between deep breaths, VT1 has been determined and the test is complete.

This ability will be the determining factor in the duration of the test. At any point while below VT1, the exerciser should be able to string together 5-10 words between deep breaths. Once they struggle to reach 5 to 10 words consecutively the test has been completed and VT1 reached.

Equipment: Cardio modality (treadmill, cycle ergometer, elliptical, etc.), stopwatch, heart rate monitoring equipment (watch and/or strap), cue cards with pre-determined phrases written on them.

Procedure

1. Measure pre-exercise heart rate.
2. Allow the exerciser to warm up on the modality the test will be performed on. The heart rate should stay below 120 bpm while the tester goes over the predetermined written or memorized phrases.
3. Once the warmup is completed, increase the intensity to bring the heart rate steady state up to 120 bpm. On a perceived rating of exertion scale, this level should feel like a 3 or 4.
4. When a steady state is achieved, have the exerciser talk continuously for 20 to 30 seconds.
5. Ask the exerciser if speaking was challenging or difficult at this level.
6. Proceed with incremental increases and repeat the steps until VT1 is found.
7. Notate the heart rate at VT1.
8. Allow the exerciser to cool down for 3 minutes at the warmup intensity level.

The heart rate limit established from the VT1 test delineates the base heart rate for sports conditioning and should operate as a guide for purely aerobic conditioning vs the beginning stages of anaerobic conditioning.[9]

VT2 Talk Test

The VT2 Talk Test will determine the point at which blood lactate rapidly accumulates inside an exerciser's body. The VT2 test is optimally performed using lactate analyzers that continuously measure blood lactate levels.

The equipment required is both cost and procedurally-prohibitive for most fitness training professionals, so VT2 field tests are a practical alternative to estimate VT2.

Equipment: Cardio modality (treadmill, cycle ergometer, elliptical, etc.), stopwatch, and heart rate monitoring equipment (watch and/or strap).

Procedure

1. Before starting, review the test purpose and discuss the intensity level the test will be performed at. The goal is maximum sustained intensity for 20 minutes.
2. Have the participant perform a 3–5-minute warmup on the modality being used for the VT2 test. Heart rate should remain at or below 120 bpm.
3. Increase the intensity to the predetermined level.
4. The participant can adjust the intensity as needed during the first few minutes of the test so they can finish the entire 20-minute test.
5. During the last 5 minutes of the test, record the participant's heart rate each minute.
6. Once completed, find the average heart rate for the last 5 minutes of the test.
7. Multiply the average heart rate by .95 to determine the VT2 estimate.

VT2 results

The limit established by the VT2 test should mark the maximum efficiency of the individual in their ability to buffer lactic acid out of the body through oxygen delivery.[10]

The VT2 limit establishes guidelines for high-intensity interval training (short-duration sprint repeats) which can improve lactic acid buffering efficiency. The improved efficiency has been shown to increase VO_2 max over time.[11]

Selecting a Testing Modality

Identifying the right cardio modality to use for testing depends on the participant's profile. Comfort with a particular modality due to prior use or application to their chosen sport will typically be the determining factors.

In certain situations, due to lack of access to equipment or risk of injury, accommodations can be made.

Below is a breakdown of common modalities with the pros and cons for testing based on a user's capabilities and common checkpoints for form while using the modality.

For upper extremity injuries a traditional cycle ergometer and potentially a stair stepper can be utilized to limit exertion on the injury.

For lower extremity injuries, an upper body only cycle ergometer can be utilized for a submaximal test.

Treadmill

Pros

- Direct carryover to real world activities
- Ideal modality for many sports applications
- Ideal for maximal intensity testing procedures

Cons

- High impact modality
- Potentially too intense for beginners above walking speed·
- May be unsuitable for clients with lower extremity injuries

Form Checkpoints

1. Toes pointing straight ahead on foot strike.
2. Foot strike plants directly under the body.
3. Knee points in the same direction as toes.
4. Hips face forward.
5. Torso remains tall without shoulder rounding.
6. Arms swing front-to-back without crossing midline.
7. Eyes stay parallel to the floor with head up.

Coaching Cues

1. Advise the participant to try to utilize a normal stride, not adjusting for being on a machine.
2. Placing the treadmill at 1% incline greater reflects real world running.
3. Since the belt moves below the participant, remind them to make a full cycle of the legs and pick heels up with each stride.

Stair Stepper

Pros

- Low impact
- Varied intensity capabilities

Cons

- The learning curve for proper form
- The bulkiness of the machine can make communication and testing procedures difficult

Form Checkpoints

1. Body stays upright throughout use.
2. Lightly hold handrails or let arms swing freely, handrails should not support bodyweight.
3. Hips should stay directly under the torso.
4. Plant and step through the entire foot allowing the heel to drop

Coaching Cues

1. Inform the user to treat the stepper like a real-world stairwell and not rely on the handrail.
2. Fully extend the leg every step in an attempt to drive the stairs down to better simulate moving up stairs.

Elliptical

Pros

- Low impact
- Total body exercise

Cons

- Unnatural movement pattern
- Lower overall exertion makes it less ideal for maximal-intensity tests

Form Checkpoints

1. Always maintain a tall upright posture.
2. Shoulders should stay relaxed and depressed.
3. Maintain a small bend in the elbow.
4. Loose grip on the handles.
5. Hips stay neutral under the torso.
6. Toes and knees point forward.

Coaching Cues

1. Remind the participant that the elliptical is a total body combination machine. The lower and upper body should work in unison.

Rowing Machine

Pros

- Low impact
- Effective for high-intensity testing

Cons

- Steeper learning curve than other modalities
- Potential users more limited due to injury risk
- Not advised for individuals with a history of lower back injury

Form Checkpoints

1. The starting position is straight arms holding the handle with a prone grip and bent knees with feet in the stirrups. Shoulders should be slightly in front of hips.

2. In the drive phase, the knees extend near-maximally first, followed by hips hinging and the torso leaning back with a neutral spine, and finally, the arms follow through and pull the handle to meet the torso at the lower chest.
3. The recovery phase should be a mirror image of the drive phase.

Coaching Cues

1. The rowing form should activate the gluteal muscle group and feel similar to a deadlift movement.
2. Maintain a neutral spine throughout the motion.

Cycle Ergometer

Pros

- Low impact
- High intensity
- Setup facilitates easy monitoring

Cons

- Test results will vary if a client is a trained cyclist independent of CRS fitness

Form Checkpoints

1. On the extension phase the driving leg should near maximal extension.
2. Back should remain flat throughout use.
3. Relaxed grip on the handlebars to ensure the upper body doesn't perform isometric exercise and hold tension.
4. Opposing limbs should look symmetrical from in front or back of the ergometer.

Coaching Cues

1. If using an upper body cycle ergometer, the same cues apply to the upper extremities vs lower extremities on a traditional cycle ergometer.
2. Align the seat height so at full extension the participant's knees are only slightly flexed.
3. The handlebars are there for balance support and shouldn't absorb a lot of body weight. Additionally, keep the feet and legs relaxed for an upper body ergometer.

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Chapter 12

Principles of Aerobic Training Programs

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Introduction

Proper programming of aerobic exercise is an integral part of any comprehensive fitness plan. Knowing when and how to incorporate different aerobic modalities will help fitness professionals guide their clients toward specific goals and health markers.

In addition, knowing which adaptations aerobic training creates establishes a deeper understanding of the benefits of aerobic conditioning on a physiological level.

The minimum guidelines for aerobic exercise, created by the American College of Sports Medicine in 2007, and re-affirmed by the Department of Health and Human services in 2018, are as follows:

1. 150—300 minutes of moderate-intensity physical activity

   or

2. 75—150 minutes of vigorous-intensity physical activity per week.

While these are the minimum recommended aerobic exercise total duration each week, more aerobic activity provides greater proportional benefit.

Most clients will benefit from a combination of aerobic and resistance training. This is referred to as concurrent training and requires specific programming considerations. The most critical factor for concurrent training is fatigue management, as overall training volume is high and clients may not be able to sustain the program for prolonged mesocycles.

Therefore, performing aerobic exercise and strength training in the same session is not advisable for beginner or intermediate clients. Older research has concluded that aerobic exercise has an inhibitory effect on muscular strength and hypertrophy adaptations.[2] However, newer research calls this into question.

Recent research concludes that the interference effect is nullified if cardio and strength workouts are not performed in the same session when training volume is equated. Thus, a key programming question is how to integrate both aerobic and strength training without sacrificing the training volume or quality of either.

Acute Physiological Responses to Aerobic Exercise

Acute responses to aerobic exercise can be divided by system: cardiovascular, respiratory, endocrine, and metabolic responses. The extent and duration of these responses are linearly related to exercise intensity.

In laboratory conditions, aerobic exercise intensity is quantified as a percentage of $\dot{V}O_2$ max. $\dot{V}O_2$ max is defined as the maximum volume of oxygen that can be consumed (utilized by the tissues) per minute. Another commonly used measurement of intensity is heart rate [HR].

Cardiovascular Responses

The cardiovascular system (heart and vessels) responds to exercise by increasing the delivery of oxygen to working muscles in order to maintain exercise performance. This includes vasodilation of the blood vessels and an increase in the work capacity of the heart muscle.

At rest, the sympathetic and parasympathetic nervous systems create a balance between stimulation and inhibition of the heart respectively. As exercise intensity increases, the sympathetic nervous system increases stimulation, while the parasympathetic system decreases inhibition. The result is an increase in heart rate and stroke volume.

Stroke volume describes the amount of blood ejected from the left ventricle per heartbeat. The product of HR x SV is referred to as cardiac output [CO, $\dot{Q}$]. Heart rate is measured in beats per minute, and stroke volume is measured in liters per beat; therefore, the units of $\dot{Q}$ are liters per minute.

Stroke volume increases as a result of greater stimulation from the sympathetic nervous system during exercise. However, there is also a mechanical stimulus responsible for the increase in SV. The increase in SV results in an increase in the amount of blood which returns to the heart via the veins: this is referred to as venous return.

The Frank-Starling Mechanism

The increased venous return during exercise results in the expansion of the cardiac muscle tissue. This results in stored elastic potential energy within the tissue. During heart muscle contraction, elastic energy is released which increases the amount of blood ejected from the ventricles.

This increased blood volume ejection due to the increased elastic energy in the heart is known as the Frank-Starling mechanism and assists the body during exercise in providing sufficient oxygen.

Thus far has been a discussion about changes specifically in the heart during aerobic exercise, but changes also occur in the vessels themselves. At the onset of exercise, a vasodilator, Nitric Oxide, secretes within the vessel walls, increasing their inner diameter. This increase in inner diameter reduces the resistance to blood flow; resistance to flow is referred to as total peripheral resistance [TPR], and also contributes to the overall increase in stroke volume. At the same time, skeletal muscle contracts around veins; this constricts them, increasing venous pressure. This increase in venous pressure aids in venous return.

Finally, active respiration (heavy breathing during exercise) increases venous return by creating a pressure gradient between the thorax and the abdomen, referred to as the respiratory pump. During exercise, blood flow redirects away from the core of the body, towards skeletal muscle to aid in exercise performance.

Blood pressure [BP] (measured in mmHg) is the force blood exerts on vessel walls; it is measured as the ratio of force during contraction (systole) versus relaxation (diastole). During aerobic exercise, systolic BP increases linearly with exercise intensity. However, in a healthy heart, diastolic BP changes very little.

As a result, the mean arterial pressure [MAP] increases linearly with exercise intensity. MAP cannot be calculated as the simple arithmetic average of systole and diastole because the heart spends more time in diastole than systole. Therefore, the following formula is used:

$$MAP = DBP + [.333 \times (SBP - DBP)]$$

A metric of the oxygen demand placed on the heart is the rate pressure product [RPP] and can be expressed as the product of HR x SBP.

Key Formulas:

- $\dot{Q} = HR \times SV$
- $MAP = DBP + [.333 \times (SBP - DBP)]$
- $RPP = HR \times SBP$

Respiratory Responses

Respiratory responses to exercise include an increase in breathing rate and depth and are mostly linear in nature. As exercise reaches maximal levels, respiratory rate increases exponentially to help buffer body pH in response to an increasing amount of lactate in the cells and bloodstream. At rest, the volume of air inhaled and exhaled naturally is referred to as Tidal Volume, with the average breathing rate at rest approximately 12 breaths per minute. Breathing frequency reaches as high as 45 breaths per minute as exercise reaches maximal levels, with breathing depth increasing steadily until it plateaus at about 70 percent $\dot{V}O_2$ max.[9]

The Respiratory Exchange Ratio [RER or RQ] describes the ratio of carbon dioxide exhaled to the volume of oxygen consumed. Metabolic gas analyzers measure the RER at the mouth in laboratory settings. The ratio is expressed via the following formula:

RER = VCO2/VO2

The RER is an estimate of fuel utilization at rest and during exercise. At rest, a non-fasted person with a normal (non-ketogenic) diet has an average RER of .82, which means that 60 percent of their total energy production derives from fat, while the remaining 40 percent derives from carbohydrates.[7] As exercise intensity increases the preferred energy source shifts from fat to carbohydrates.

It is important to note that RER values above 1.0 are routinely observed in laboratory testing. This is due to the fact that RER is measured at the mouth and is therefore affected by breathing rate. At a certain exercise intensity, ventilation increases exponentially, not linearly with exercise intensity, this is referred to as the ventilatory threshold (VT).

This does not occur due to oxygen demand. Rather the high breathing rate is necessary to maintain pH when high levels of lactate are being produced. As a result, RER levels at maximum exercise are often observed to be 1.1 or higher.

Metabolic Responses

During aerobic exercise, the body supplies ATP to working muscles through both aerobic and anaerobic means, with anaerobic means supplying the majority of ATP at higher intensities. Thus, the higher the exercise intensity, the greater reliance on anaerobic sources of ATP (phosphocreatine and glycolysis).

However, these sources are finite, meaning that high intensity exercise can only be maintained for a relatively short period of time. Ultimately, the onset of fatigue is, at least in part, due to the availability of carbohydrates and fats for oxidation in working muscles to produce sufficient ATP.

Endocrine Responses

During exercise the endocrine system facilitates fuel availability and uptake by muscle cells. The hormones of interest include the following: epinephrine, norepinephrine, glucagon, insulin, cortisol, and growth hormone.

Glucagon and Insulin

The pancreas produces and circulates glucagon and insulin. Glucagon and insulin are regulatory hormones that control blood glucose levels by moving glucose molecules in and out of cells. Specifically, insulin lowers blood glucose levels by binding to glucose molecules and transporting them across cell membranes via specialized channels called GLUT4 transporters. In essence, insulin lowers blood glucose and increases glucose availability in cells for glycolysis.

Glucagon does precisely the opposite, it increases blood glucose levels by moving glucose molecules out of cells and into the bloodstream. Glucagon also stimulates the breakdown of glycogen (the stored form of glucose) into glucose.

During exercise, blood concentrations of insulin decrease, and other mechanisms which move glucose into cells increase. Furthermore, glucagon levels increase, improving insulin sensitivity. The combination of the two also leads to an increase in fat breakdown (lipolysis), resulting in more fatty acids available for fuel.

Cortisol and Growth Hormone

The adrenal cortex releases cortisol, a hormone with wide-ranging effects. In the context of exercise, cortisol primarily stimulates the conversion of amino acids into fuel sources and intermediates for aerobic exercise.

Cortisol encourages the breakdown of muscle proteins in order to facilitate the conversion of some amino acids into glucose or intermediates for the Krebs cycle. Cortisol concentrations are directly related to exercise intensity, with higher intensity correlating to higher cortisol levels in the blood.[3] Growth hormone is secreted from the anterior pituitary gland and increases cortisol and glucagon levels in the blood.

Epinephrine and Norepinephrine

Lastly, epinephrine and norepinephrine (collectively referred to as the catecholamines) are stimulatory and inhibitory endocrine responses respectively; they are colloquially referred to as the “fight or flight” hormones. The adrenal medulla releases these hormones when the body perceives stress, such as in physical exercise. They increase heart rate and blood pressure, delivering more oxygenated blood to working muscles in order to maintain exercise performance.

In summary, exercise leads to increases in glucagon, cortisol, growth hormone, epinephrine, and norepinephrine concentrations. Plasma concentrations of these hormones directly correlate to exercise intensity. Their collective effects facilitate the availability of oxygen and other nutrients necessary for the production of the ATP.

Long-term Adaptations to Aerobic Exercise

Long-term adaptations to aerobic exercise can be divided into the following categories: cardiovascular, respiratory, musculoskeletal, metabolic, and endocrine. This section reviews each of these systems as well as examines the effects on body composition and exercise performance. Understanding these effects aids the personal trainer as they set long-term goals with their clients, as well as guide programmatic decisions at the mesocycle and macrocycle level.

Cardiovascular Adaptations

Maximal aerobic power is expressed by the Fick Equation:

$\dot{V}O_2$ (L/min) = $\dot{Q}$ x a- O_2 difference.

As previously mentioned, cardiac output [$\dot{Q}$] is the product of stroke volume and heart rate, and measures the amount of blood, in liters, pumped into systemic circulation per minute. The a-O_2 difference is the difference in oxygen concentration in arterial versus venous blood, thus it measures how much oxygen the cells extract from the blood. The Fick equation represents both oxygen delivery ($\dot{Q}$) and oxygen extraction (a- O_2 difference). Chronic adaptations to aerobic exercise occur in both oxygen delivery and extraction.

The primary adaptations in cardiac output occur via increases in stroke volume. Long-term cardiovascular exercise results in hypertrophy of the cardiac muscle cells, specifically in the left ventricle.

This results in a larger left ventricle cavity and a stronger contractile function of the ventricle walls. Meanwhile, filling time (the period of time in which the bicuspid and tricuspid valves are open) increases. An increase in blood volume also results from chronic cardiovascular training.[11] These factors combine to increase stroke volume.

Maximal heart rate is largely genetic and age dependent and cannot be changed via exercise. However, at resting and submaximal exercise, a reduction in heart rate is observed. Three mechanisms explain this phenomenon:

- Increase in parasympathetic stimulation
- Decrease in sympathetic stimulation
- Lower intrinsic heart rate[4]

The effect of long-term aerobic exercise on blood pressure varies based upon resting BP and overall health of the client. For individuals with normal blood pressure, average changes are very small. On the other hand, in individuals with hypertension (SBP> 140 OR DBP > 90 mmHg) scientists have observed more substantial reductions.[8]

Furthermore, the reductions in blood pressure following a bout of aerobic exercise have been observed and are termed "postexercise hypotension." Finally, as the left ventricle hypertrophies, SBP decreases for a given submaximal workload. This demonstrates an improved aerobic capacity in response to long-term term training.

Respiratory Adaptations

Respiratory adaptations to long-term aerobic exercise are less robust than the adaptations observed in other systems. However, a few changes at both sub-maximal and maximal work rates occur in minute ventilation, and ventilatory efficiency.

Minute ventilation ($\dot{V}_E$) decreases at submaximal work rates by a significant amount.[4] However, $\dot{V}_E$ increases at maximal work rates. This is because at submaximal work rates tidal volumes increase but breathing frequency either stays the same or slightly decreases. In maximal work rates both frequency and tidal volume increase.

Another adaptation to long-term aerobic training is hypertrophy of the diaphragm and other muscles used during active breathing. This results in a decreased oxygen cost of ventilation, thus an increase in efficiency. This efficiency frees up more oxygen for use in other muscles while still meeting the oxygen needs of the muscles used in active breathing.

Musculoskeletal Adaptations

Aerobic activity stimulates type I muscle fibers with little to no effect on type IIa or IIx fibers.[11] Research evidence suggests that some mild shifting in fiber type may occur, resulting in a shift away from IIx and IIa towards type I fiber types.

However, the extent to which this occurs, and the duration of training needed to stimulate it remain unclear.[10] This potential shift would result in a decrease in the maximum velocity of shortening and peak force production of a muscle fiber along with an increase in fiber efficiency, aerobic capacity and fatigue resistance.

Bone and Connective Tissue Adaptations

Bone mineral density [BMD] describes the amount of bone mineral content per unit volume of bone tissue. BMD is the standard measurement of bone strength; it rises through childhood and early adulthood, plateaus in middle age, and declines later in life.

Resistance training exercises, specifically activities which load the hips and axial skeleton, have been shown to be the most effective.[5] However, aerobic activities, such as running, have also been shown to improve BMD.[5] Lower impact activities such as walking, aquatics, and upper body cycling have not been found to be beneficial for bone adaptation.

Metabolic Adaptations

Within type I muscle fibers, numerous adaptations occur that enhance the fiber's capacity to produce ATP aerobically. Capillary density, defined as the number of capillaries surrounding one muscle fiber, increases substantially over a period of a few weeks to two months. This increases oxygen supply and the rate of waste removal.

There is also an increase in the concentration of cellular myoglobin, a molecule that transports oxygen from the cell wall to the mitochondria. Other enzymes and molecular transporters increase in intracellular concentration as well. Mitochondrial density also increases, albeit more slowly than myoglobin concentrations or capillary density.

In addition to oxidative capacity, type I muscle fibers also increase glycogen storage. Glycogen, the stored form of glucose, produces ATP via the anaerobic pathway, through glycolysis. Glycolysis provides a fast means of producing ATP and is used by cells in conjunction with aerobic metabolism to meet ATP demands.

In summary, long-term aerobic exercise training results in increased capillary density, myoglobin, oxidative enzymes, and mitochondrial density. The collective effect improves the fiber's ability to utilize oxygen to produce ATP.

Measuring Aerobic Intensity

Direct measurement of aerobic power output ($\dot{V}O_2$) is not practical outside of laboratory conditions. However, heart rate correlates strongly to $\dot{V}O_2$ and is easily measured manually or with optical or electrical monitors. Maximal heart rate directly relates to age and can be calculated through various equations, the simplest of which is the age-predicted maximal heart rate formula:

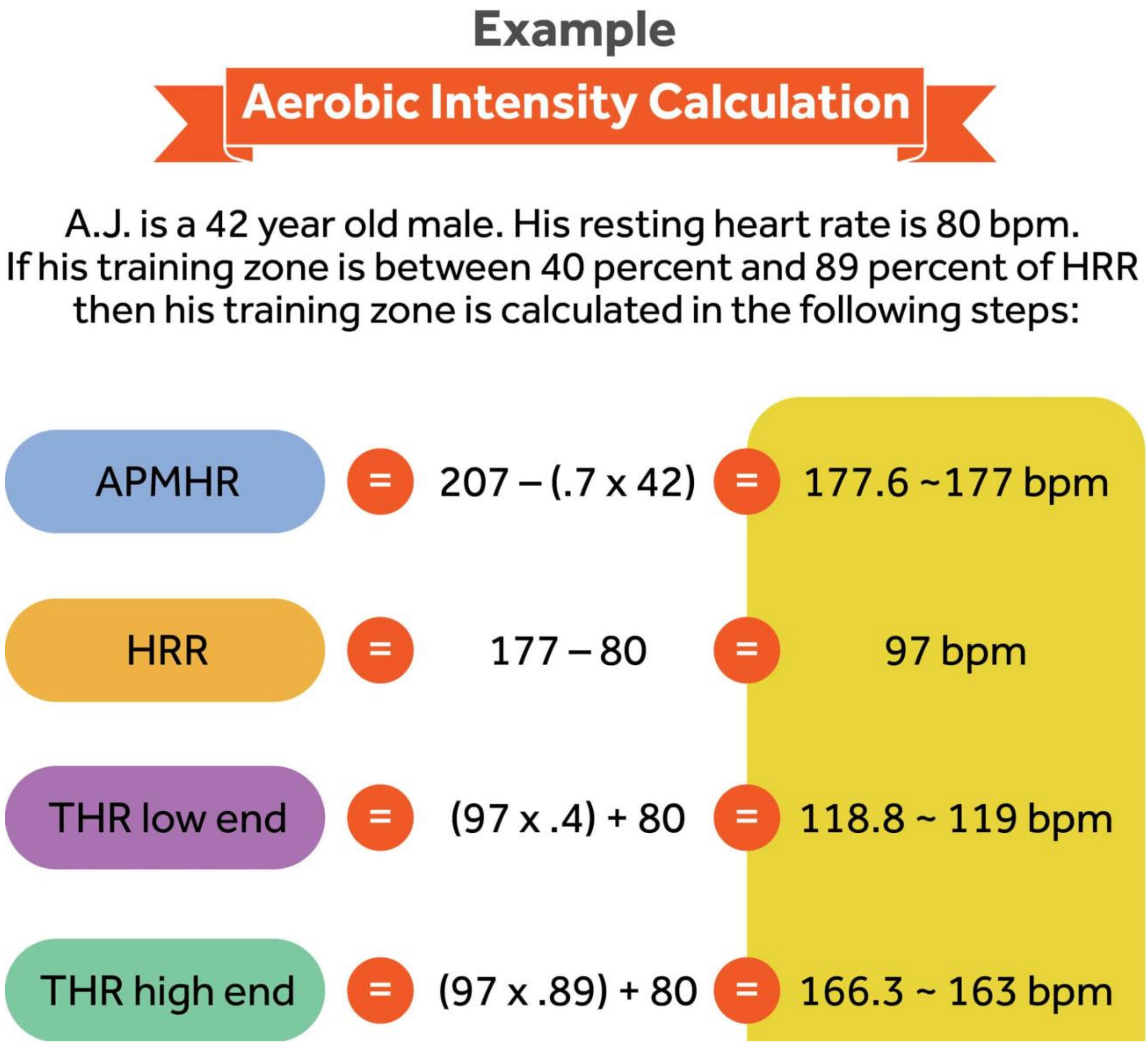
APMHR = 220 – AGE

This equation has been shown to be accurate within approximately 10 – 15 beats.[11]

A more accurate measurement is the Karvonen formula or heart rate reserve method (HRR), which incorporates resting heart rate (RHR) instead of using age-predicted max heart rate. The Karvonen formula is:

HRR = APMHR – RHR

Target HR (THR) = (HRR x exercise intensity) + RHR



To accurately measure resting heart rate, clients must measure their heart rate early in the morning, typically immediately after waking up naturally, prior to the ingestion of any stimulants such as caffeine.

Subjective measurements of aerobic exercise intensity are also available, such as the talk test, or the rate of perceived exertion (RPE). The talk test measures intensity based upon the ease with which the client can carry a conversation during aerobic exercise.

If a client is able to carry a full conversation with no difficulty, intensity is likely low. On the other hand, if they are unable to speak at all, intensity is high, bordering on maximal. The RPE scale was originally a 6 – 20 scale which correlated to heart rate during aerobic exercise. A more common RPE scale is the modified 0—10 scale. In either case, clients subjectively report their level of exertion, which can be correlated to low, medium, or high intensity.

Aerobic Training Protocols

As with all exercise programs, the principles of specificity, overload, and periodization apply. The principle of specificity states that the body will adapt to the stimulus to which it is exposed, meaning that in order to trigger adaptations in specific muscle groups and systems, they must be targeted during training.

The principle of overload states that these muscle groups and systems must be exposed to a greater level of exertion than normal in order for them to adapt. This can be in the form of greater intensity, and/or greater duration of the stimulus.

Lastly, the principle of periodization states that overload can only be maintained through specific, measured, and gradual increases in stimulus over time. Furthermore, periodization also states that the body must experience periodic reductions in stimulus in order to re-sensitize the adaptive pathways and allow for sufficient recovery from training.

The basic variables of exercise program design are: frequency, intensity, and duration. Frequency refers to the number of aerobic sessions per week. Intensity is a measurement of how hard a training session is, as mentioned it is measured either objectively (APMHR, HRR, etc..) or subjectively (talk test, RPE). Duration refers to the minutes of actual training, warm-ups and cool-downs are not included.

Frequency of Aerobic Training

The number of aerobic training sessions per week will depend upon client training status and fatigue management. The minimum recommended guidelines for aerobic exercise are 150—300 minutes of moderate intensity exercise per week or 75—150 minutes of vigorous activity per week.

Beginner clients will focus more on moderate intensity sessions spread evenly throughout the week. As clients progress, vigorous sessions can be added, replacing moderate sessions. If clients manage their fatigue well via proper sleep and nutrition, weekly progressions are expected.

Intensity of Aerobic Training

Training zones vary based upon the calculations used to gather intensity data. Using a percentage of APMHR from between 64 percent to 95 percent will provide an appropriate stimulus to improve aerobic fitness. If HRR is used, a smaller range, 40 percent to 89 percent should be used. When creating an aerobic training protocol for clients, calculate a target heart rate range by using either formula twice, a low end, and a high end. Consider the example below, using the HRR formula.

A.J. is a 42 year old male. His resting heart rate is 80 bpm. If his training zone is between 40 percent and 89 percent of HRR then his training zone is calculated in the following steps:

APMHR = 207 – (.7 x 42) = 177.6 ~177 bpm

HRR = 177 – 80 = 97 bpm

$THR_{low\ end}$ = (97 x .4) + 80 = 118.8 ~ 119 bpm

$THR_{high\ end}$ = (97 x .89) + 80 = 166.3 ~ 163 bpm

Most clients will have little familiarity with subjective exercise scales, as a result their initial RPE reports will be quite inaccurate. This is further complicated by the fact that many novice exercisers have not experienced true maximal or near maximal level exercise, so they cannot accurately say what a "10 out of 10" feels like.

However, research in the last five years has shown that repeated use of the RPE scale during the same exercise modality improves its reliability and validity.[6] Combining RPE and HR measurements will accelerate this process.

Wearable Aerobic Equipment (Fitness Trackers)

The last two decades have seen a boon in wearable exercise technology including accelerometers, pedometers, electrical and optical heart rate monitors, and GPS units. The wealth of options has driven the cost down, making devices practical and affordable for the average consumer.

Accelerometers and pedometers measure activity via a pendulum which swings in time with each stride, completing an electrical circuit and allowing a microchip to track. They are highly effective at measuring steps, but less accurate at quantifying other forms of physical activity. Electrical heart rate monitors measure heart rate via a chest strap, which detects electrical activity in the heart and then calculates heart beats per minute.

Optical heart rate monitors measure heart rate via infrared measurement of blood vessel perfusion. These are typically worn on the wrist via smartwatch. They have been shown to be very accurate for steady state exercise, with a higher error rate during interval exercise. Lastly, GPS trackers connect to a network of satellites and triangulate position, direction, speed and other kinematic variables.

Wearable technology, such as those mentioned above, can provide trainers a wealth of quantitative data regarding clients' performance, both during sessions and beyond. Quite a few wearables even track recovery variables such as resting heart rate, sleep quantity and quality. They can also be used to estimate basal metabolism and therefore provide info for dietary programming. Given their usefulness they are fastly becoming an essential part of every trainer's toolkit, although there is room for error, so consider that when using these devices.

Summary

Aerobic training creates many short and long-term changes in the body.

On an acute basis, the heart increases vasodilation of the blood vessels and an increase in work capacity, resulting in greater heart rate and stroke volume. Systolic blood pressure goes up along with respiratory rate, ATP production, epinephrine, norepinephrine, glucagon, cortisol, and growth hormone, while insulin decreases.

Chronic cardiovascular exercise results in hypertrophy of the cardiac muscle cells, improved aerobic capacity, an increase in oxygen efficiency, stimulation of type I muscle fibers, some small strength changes in bone adaptation, increased capillary density, myoglobin, oxidative enzymes, and mitochondrial density.

When perscribing cardiovascular exercise programs, fitness professionals should be aware of general exercise principles and be able to set and track target heart rate intensities using the modern technology available to them.

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Chapter 13

Principles of Flexibility Training Techniques

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Introduction

Flexibility training is a key component of comprehensive fitness training. Flexibility training techniques encompass a very broad range of activities that are best utilized in a specific, progressive fashion.

Flexibility can be defined as the ability of a joint to move through its complete ranges of motion without injury.[1,12] This ability is dependent on the optimal function of the musculature surrounding a joint, including the ability to both flex and extend without impediment.[2]

For otherwise healthy individuals, greater flexibility tends to reduce the rate of injuries incurred in training and day-to-day life.

Ideal flexibility allows muscle tissue to contract, relax, and synergistically work with all muscles supporting a moving joint or series of moving joints.[1,2]

The two major concepts of flexibility are elasticity and plasticity.

Elasticity is the ability of the muscle-tendon complex to return to its original state following a movement pattern.[3] Through both lengthening through a stretch phase and contracting under resistance, fluidity of elastic potential has been shown to reduce potential muscle injury.[4] Plasticity refers to how skeletal muscle adapts to the load and stress placed upon it.[5] Muscle tissue will grow in response to healthy stimuli or deteriorate if it is not utilized.[6]

Factors Affecting Flexibility

Age

Independent of other factors, aging is associated with a decrease in flexibility.

Sex

Women demonstrate greater ROM than men while also exhibiting a higher stretch tolerance.

Temperature

Heat increases flexibility and reduces injury through reduced internal friction and decreases the energy cost of muscular contraction. Cold has the opposite effect, decreasing and limiting flexibility.

Activity Level

Regular activity does promote improved flexibility levels. Regular participation in strength training correlates to an increase in overall flexibility in most.

Repetitive Motions

Research shows the stress of repetitive motions including in sports, occupation, and daily living correlates with a decrease in the flexibility of the associated joints.

Body Composition

Greater waist circumference and obesity link to a reduction in flexibility due to mechanical obstruction.

Joint Structure

All the joints of the human body fall into a specific structure wherein they have a certain natural range of motion. Based purely on design, a ball and socket joint will have a greater degree of range of motion than any other joint.

Tissue Extensibility

Healthy muscle tissue exhibiting high extensibility will have more flexibility and range of motion. Changes in the mechanical properties of muscle fascia directly impede overall flexibility. Tightness from lack of tissue extensibility results from an increase in tension in either active (muscle) or passive (tendon/ligament) structures, limiting extensibility.

Multiple factors have been shown to limit flexibility and someone's ability to improve their own safe range of motion. The factors most likely to affect overall flexibility include gender, age, temperature, activity levels of the individual, repetitive motions (pattern overload), body composition, prior Injury, joint structure, and tissue extensibility.[7]

- Sex: Women demonstrate greater ROM than men while also exhibiting a higher stretch tolerance, according to research.[8, 16]
- Age: Regardless of gender, aging has been correlated to a decrease in flexibility.[9, 11]
- Temperature: Heat increases flexibility and reduces injury through reduced internal friction and decreases the energy cost of muscular contraction. Cold proves the opposite, decreasing and limiting flexibility.[10]
- Activity Level: Regular activity does promote improved flexibility levels.[11] Regular participation in strength training correlates to an increase in overall flexibility in most.
- Repetitive Motions: Research shows the stress of repetitive motions often used by athletes but not limited to them, correlates with a decrease in flexibility of the associated joints.[13]
- Body Composition: Greater waist circumference and obesity directly link to a reduction in flexibility due to mechanical obstruction.[9, 14]
- Prior Injury: Limitations in flexibility due to injury have been well documented over time. Reasoning includes joint disfiguration, scar tissue development, and muscular maladaptation.[13, 15]
- Joint Structure: All the joints of the human body fall into a specific structure wherein they have a certain natural range of motion.[17] Based purely on design, a ball and socket joint will have a greater degree of range of motion than any other joint.[15, 17]
- Tissue Extensibility: Healthy muscle tissue exhibiting high extensibility and flexibility allows for greater flexibility.[15, 18] Changes in the mechanical properties of muscle fascia including thickness and tightness directly impede overall flexibility. Tightness results from an increase in tension in either active (muscle) or passive (tendon/ligament) structures, limiting extensibility.[18,19]

Benefits of Flexibility Training

A flexibility training program has the goal of lengthening the distance between a muscle's origin and its insertion.[19]

Generally, muscle tension is inversely related to muscle length. This means that the longer the muscle, the less tension it should hold.

The success of a flexibility training program is typically determined by measurable increases in the range of motion as the program progresses.[19]

Increased range of motion offers many performance advantages in sports and other physical activities. Some sports have inherently high flexibility requirements, while other sports do not require as much flexibility.

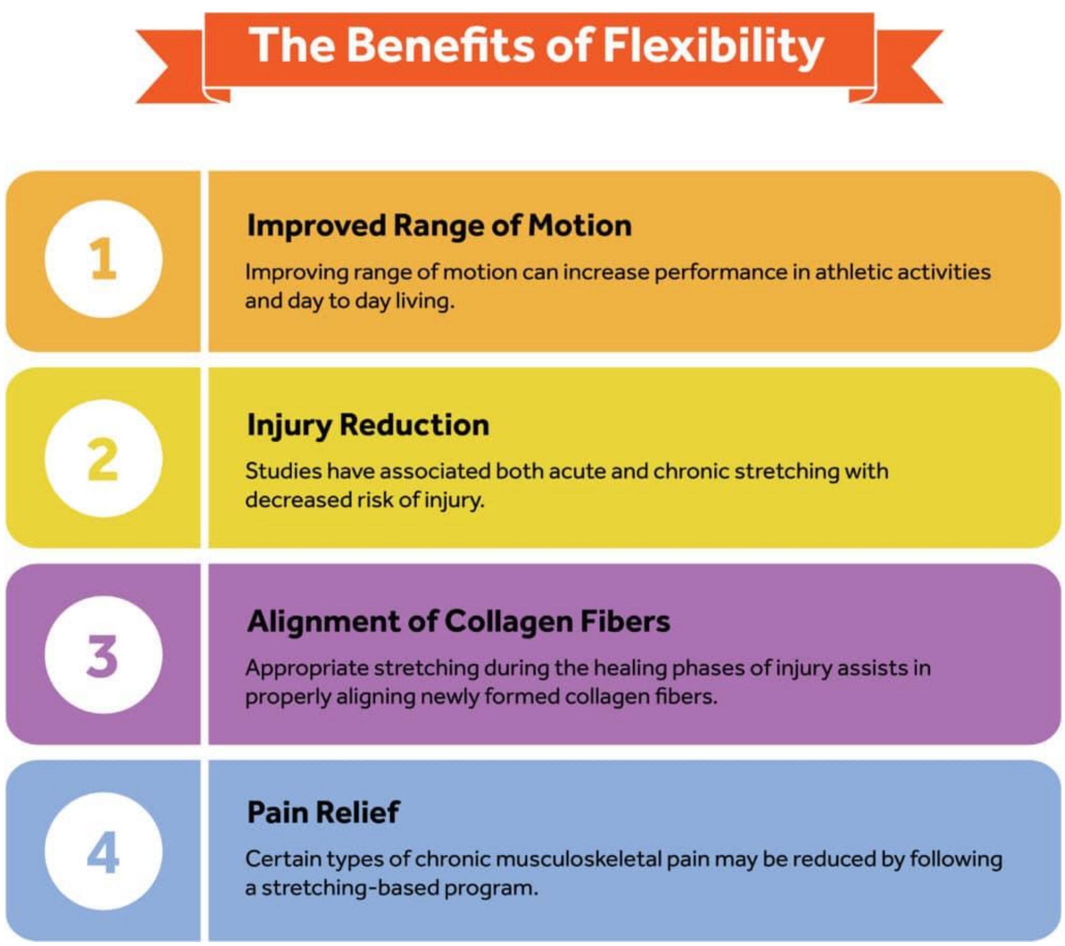
Nevertheless, athletes across many sports with a less-than-normal range of motion typically benefit from improved flexibility.

Another benefit of improved flexibility is injury reduction. One particular study around workplace injuries had subjects perform a variety of stretching exercises. During the course of the study, subjects reported reduced discomfort and demonstrated an increased range of motion, thereby decreasing the likelihood of injury.[20]

Additional research suggests that both acute and chronic stretching is associated with decreased injury frequency.[33]

In addition to muscle lengthening, an additional benefit of stretching lies in the alignment of collagen fibers within the muscle tissue.

Specifically, in cases of rehabilitation and healing tissue, proper stretching has been shown to improve recovery.[19] Pain relief is another useful application for a stretching program. In certain cases, studies indicate that stretching has been performed as well as strength training and yoga for the relief of chronic musculoskeletal pain.[19, 21]



Types of Stretching

Static Stretching

Static stretching involves extending the targeted joint to the point of discomfort at the end range of flexibility, then holding the end position for 30 seconds or more for one or more sets.[24]

The cumulative effect relaxes the stiffness in the targeted muscle and muscle-tendon unit.[25] Research shows that muscle-tendon unit stiffness is commonly linked to soft tissue injury.[22, 23]

By utilizing a slow and controlled lengthening of soft tissue, static stretching improves flexibility in a range of motion tests, passive torque, and passive stiffness.[23, 28]

Dynamic Stretching

Dynamic stretching involves loosening muscle tissue through a series of whole-body active range of motion exercises. The rhythmic movements of the muscles elevate body temperature, enhance motor-unit excitation, improve kinesthetic awareness, and improve active range of motion.

Typical exercises used during a dynamic stretch include leg swings, skipping, and jumping.[26] The effects from dynamic stretching have been determined to be limited and only effective in the acute phase when measuring stiffness and range of motion.[26, 27]

Ballistic Stretching

Ballistic stretching utilizes the body's momentum through repetitive bouncing movements at or near the end range of motion. Immediately post ballistic stretch, an increase in range of motion has been noted, but the findings are controversial. No long-term benefit around ballistic stretching has been found.[28, 29]

Of all the varieties of stretching, ballistic stretching has been shown to be potentially harmful as a byproduct of the muscle tissue contracting when the muscle spindle is stimulated in response to rapid stretching in the muscle.[28]

Proprioceptive Neuromuscular Facilitation (PNF)

Stretchers perform PNF via a series of contractions by the shortened muscle group followed by a combination of full relaxation, followed antagonistic contraction, which facilitates muscular inhibition by activating the Golgi tendon organs of the muscle tendon unit.[30]

PNF stretching performs similarly to static stretching and thus should be used in a similar fashion. Both will show an immediate range of motion increase if done correctly. They can both temporarily reduce muscle strength, power, speed, and agility, especially if performed directly before these other modalities.[31, 32]

Recommendations for Flexibility Training

A stretching routine aims to increase the range of motion of the body by systematically targeting muscle tightness. The tightness can occur in two different scenarios.

Tight Muscles

Muscles may be tight because they are overly dominant or active.

The activation of the muscle at its resting length keeps the muscle in a shortened or contracted position. In this case, the goal of the stretching program is to lengthen the shortened muscle, thus gaining elasticity and increased potential for both extension and flexion.

Muscle Weakness and Imbalance

Muscle tightness can also occur when a muscle is too weak compared to its dominant counterpart. In this situation, the muscle is chronically lengthened as it is not strong enough to counteract the resting tension of the opposing muscle group.

In this scenario, activating and strengthening the weakened muscle can be beneficial, and can improve the range of motion independent of passively stretching the dominant muscle.

Most often, these two causes of flexibility limitations occur together. As such, the most effective stretching programs cover multiple areas of the body utilizing a range of stretching types.

Static stretches should be held for a long period of time typically 30 seconds or longer. Static stretching is a good stretching technique for developing length along the muscle-tendon unit. As mentioned, their effects can be deleterious to strength and power before exercise, so these stretches should be placed after those exercise modalities in a training session.

Dynamic stretching is best utilized as a warm-up activity accounting for the number of benefits the active range of motion exercises create. In the case of overly lengthened muscle tightness, dynamic stretching proves effective in properly warming up both sides of a force couple, creating elasticity around vulnerable joints. Dynamic stretching acutely affects tightness and is not considered the best way to create long term benefits, but is excellent for acute training benefits.

Ballistic stretching's benefits are controversial at best and can't be recommended above the other varieties of stretching in any fashion.

The utilization of proprioceptive neuromuscular facilitation should be used parallel to static stretching with more pronounced benefit in immediate range of motion increases.

For tightness created by a dominant muscle group, PNF can create an immediate range of motion improvement. If used prior to activity ideally it is paired with a dynamic warm up immediately following the stretching routine.

Warm Up Protocols

General Warm Up

To plan the warm up, trainers should look at the muscles, joints, and systems required within this exercise session to pick a combination of dynamic stretches along with light movements that prepare the body for the entire workout.

The general warm up also reveals any particular tightness the athlete is currently experiencing which may require special attention on the day of training.

Example General Warm Up for Sprinting session

Exercise	Sets	Repetitions	Purpose	Example Sprint Program
Aerobic (any modality)	1	5 minutes	Elevate heart rate and core temperature	Light jog
Dynamic exercises	1-2	12-20	Move joints through dynamic range of motion	Arm circles, arm swings, leg swings, butt kicks, walking lunges, walking side lunges
Specific warm Up	1-5	Match workout program	Prepare body for specific demands	3-5 sprints starting at low intensity and building into full speed

Specific Warm Up

Now that the client is warmed up and mobilized for the workout, they need to perform a specific warm up using the first main movement in the session with lower resistance or intensity. This specific warm up protocol should occur before the 'working sets' in most typical resistance training programs.

Performing heavy or high intensity resistance exercises requires a greater number of warm up sets. For example, a bench presser aiming to do a 5 repetition maximum (RM) with 495lbs is going to need more warm up sets than a novice aiming for a 5RM with 95lbs.

Example Specific Warm Up Before a 100m Sprinting Session

The client completes 3-5 warm up 100 meter sprints with increasing intensity prior to the target intensity sprints of the same distance.

Techniques for Select Flexibility Exercises

Static Stretches

Neck Rotation (Look Right and Left)

Target muscles:

- Levator scapulae
- Suboccipitals

Procedure:

1. With an upright torso and eyes fixed parallel to the floor, slowly rotate the head looking to the right as far as comfortable and hold at the end range of motion for 15-30 seconds.
2. After completing the stretch hold, return to the center then repeat to the left side.
3. Repeat the stretch 3 times per side.

Neck Flexion

Targeted muscles:

- Splenius capitis
- Cervicis

Procedure:

1. Start with an upright torso.
2. Slowly bring the chin towards the chest trying to tuck the chin to the sternum creating a stretch on the back of the neck.
3. Hold for 30 seconds then relax.
4. Repeat 3-5 times.

Neck Extension

Targeted muscles:

- Deep neck flexors
- Scalenes
- Sternocleidomastoids

Procedure:

1. Start with an upright torso.
2. Contract the scapulae together while trying to slide them down the back.
3. Bring the back of the head towards the back and spine stretching the front of the throat.
4. Hold for 30 seconds then relax.
5. Repeat 3-5 times.

Lateral Neck Flexion

Targeted muscles:

- Levator scapulae
- Trapezius

- Sternocleidomastoids
- Scalenes

Procedure:

1. Start with an upright torso, head pointed forward.
2. Take the right hand and gently rest it on top of the left ear with the elbow tilted upwards.
3. Let the weight of that hand slowly pull the right ear towards the right shoulder, stretching out the muscles running along the side of the neck and shoulder complex.
4. Hold for 30 seconds and then switch sides.
5. Repeat 3-5 times.

Hands Behind Back

Targeted muscles:

- Biceps
- Anterior deltoid
- Pectoralis major/minor

Procedure:

1. Start standing with fingers interlocked behind the back and arms straight.
2. Slowly lift the arms as high as possible without letting the torso lean forward.
3. Hold for 30 seconds then relax.
4. Repeat 3-5 times.

Pretzel

Targeted muscles:

- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Obliques
- Paraspinals

Procedure:

5. Start seated on the floor with the legs extended straight out in front.
6. Cross right foot over left leg, planting the right foot outside of the left knee.
7. Cross the left arm over the right thigh while placing the right arm on the floor behind the body.
8. Rotate the trunk and look over the right shoulder.

9. Hold for 30 seconds then relax.
10. Switch sides with every repetition.
11. Repeat 3-5 times per side.

Supine Hamstring Stretch

Target muscles:

- Biceps femoris
- Semimembranosus
- Semitendinosus

Procedure:

1. Start lying on the floor adjacent to a doorway or wall.
2. Lift one leg to rest on the doorway or wall while keeping the opposite foot planted on the floor.
3. Extend the elevated leg while pulling the toes towards the body to create the maximally tolerable hamstring stretch.

Forward Lunge

Target muscles:

- Hip flexors
- Rectus abdominis

Procedure:

1. Start in a half kneeling position with shoulders stacked vertically over the knee on the floor.
2. Opposite foot should be in a forward lunge position with 90-degree knee bend.
3. Squeeze glutes of the kneeling leg to drive the kneeling hip forward into extension while keeping shoulder stacked over knee.
4. Hold for 30 seconds then relax.
5. Repeat 3-5 times.

Prone Quadriceps Stretch

Target muscles:

- Rectus femoris
- Vastus lateralis
- Vastus intermedius
- Vastus medialis muscles

Procedure:

1. Lie on a mat or the floor, chest facing the ground, legs straight.
2. Bend the knee and grab the ankle with the corresponding hand.
3. Pull the ankle towards the glutes.
4. Hold for 30 seconds, then switch sides.
5. Repeat 3-5 times.

Lying Knee to Chest

Target muscles:

- Erector spinae
- Latissimus dorsi
- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Thoracolumbar fascia

Procedure:

1. Start lying on the back with legs extended and heels on the floor.
2. This stretch can be performed with either one or both legs based on user preference.
3. Pull knee(s) towards chest wrapping arms around tucked knee(s) and hugging leg(s) towards the chest.
4. Hold for 30 seconds then relax.
5. Repeat 3-5 times.

Semistraddle (Modified Hurdler's Stretch)

Target muscles:

- Biceps femoris
- Semimembranosus
- Semitendinosus

Procedure:

1. Start seated on the floor with one leg extended out in front.
2. Bend the opposite knee so that the bottom of the foot rests on the inside of the thigh of the extended leg.
3. While trying to keep the back straight, reach for the toes of the extended leg with both hands allowing the torso to fold over the extended leg.
4. Hold for 30 seconds then relax.
5. Repeat 3-5 times per side.

Butterfly

Target muscles:

- Adductors brevis
- Adductor longus
- Adductor magnus
- Gracilis

Procedure:

1. Start seated on the floor with both legs out in front.
2. Bend both knees to bring the bottoms of both feet together.
3. The closer the heels pull toward the groin, the more intense the stretch will be.
4. Hold both feet with both hands and allow both elbows to rest on both knees.

5. Keeping the torso upright, allow both knees to fall towards the floor. Additional pressure can be applied through the elbows.
6. Hold for 30 seconds then relax.
7. Repeat 3-5 times.

Wall Stretch

Targeted muscles:

- Biceps femoris
- Semimembranosus
- Semitendinosus
- Gastrocnemius
- Soleus
- Additionally, the static wall stretch will utilize gravity to promote thoracic extension through the upper back via natural compression.

Procedure:

1. Start by lying on the floor with the body perpendicular to a wall.
2. Place both legs vertically on the wall and bring the tailbone as close to the base of the wall as possible.
3. Engage quads and maintain straight legs to deepen the effect of the stretch.
4. Hold for 1 to 4 minutes.

Forearm Stretch (Flexor and Extensor)

Targeted muscles:

- Carpi ulnaris
- Palmaris longus
- Carpi radialis
- Pronator teres
- Brachioradialis
- Extensor digitorum
- Extensor digiti minimi
- Anconeus

Procedure:

1. Come down onto all fours with hands directly under the shoulders and knees directly under the hips.
2. Spread the fingers as far out as possible with the index finger pointing forward.

3. Gently rock the hips forward until the stretcher feels a stretch along their flexor muscles. Hold for 15-20 seconds.
4. Move the hips backward until they feel a stretch in the other direction along their extensors.
5. Come back to center and slowly rotate the fingers outward until the thumb is pointing forward. Repeat the same stretch.
6. Keep rotating the wrists until the fingers are pointed back towards the hips and repeat the stretch, being mindful of the stretcher's own mobility restrictions.

Dynamic Stretches

Arm Circles

Targeted muscles:

- Rotator cuff
- Anterior deltoid
- Medial deltoid
- Posterior deltoid
- Biceps

Procedures:

1. Start in a standing position with arms straight and feet shoulder-width apart.
2. Raise the arms to the side bringing them up to shoulder height.
3. Move the arms forward in a controlled circular motion.
4. Repeat 20 times then reverse the direction of the circles.

Arm Swings

Targeted muscles:

- Pectoralis major
- Pectoralis minor
- Rhomboids
- Upper trapezius
- Middle trapezius

Procedure:

1. Start in a standing position with arms straight and feet shoulder-width apart.
2. Raise the arms to the side bringing them up to shoulder height.
3. Bring the arms forward to wrap around the upper torso as if hugging the chest.

4. Release the arms back towards the start position in a swinging motion.
5. Maximize the range of motion comfortably in both directions.
6. Repeat 15 times.

Leg Swings

Targeted muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus

Procedure:

1. Start in a standing position with feet shoulder-width apart.
2. Swing one leg forward up to hip height. The leg should be straight and the toe pointed forward.
3. Swing the leg backward, bring it behind the body to hip height using gravity's momentum.
4. Repeat 15 times and switch sides.

Lunge Walk

Target muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus

Procedure:

1. Start in a standing position with feet shoulder-width apart.
2. Take one step forward allowing both knees to bend.
3. Forward knee should stay on top of the forward ankle.
4. Back knee should bend to 90 degrees and be directly under the torso.
5. Maximize range of motion throughout the lunge.
6. Step forward to return to the standing position then repeat on the opposite leg.
7. Continue for 20 lunges.

Reverse Lunge Walk

Target muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus

Procedure:

1. Start in a standing position with feet shoulder-width apart.
2. Take one step backward allowing both knees to bend.
3. Forward knee should stay on top of the forward ankle.
4. Back knee should bend to 90 degrees and be directly under the torso.
5. Maximize range of motion throughout the lunge.
6. Extend the forward leg to push back into the standing position then repeat on the opposite leg.
7. Perform 20 alternating repetitions.

Hockey Lunge Walk

Target muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus

Procedure:

1. Start in a standing position with feet shoulder-width apart.

2. Keeping one foot planted, rotate and step into a lunge at approximately a 45-degree angle. Allow planted foot to pivot on toes.
3. Moving leg should bend to 90-degrees with knee above toes.
4. Back leg will bend but doesn't touch the floor.
5. Extend moving leg to return to standing position.
6. Repeat on the opposite leg.
7. Perform 20 alternating repetitions.

Walking Side Lunge

Target muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Adductors brevis
- Adductor longus
- Adductor magnus
- Gracilis

Procedure:

1. Start in a standing position with feet shoulder-width apart.
2. Take one step laterally into a lunge.
3. Moving knee will bend and torso can lean forward.
4. Sit as low as possible onto the moving leg. Moving foot should point straight ahead and the knee should point the same direction as the second toe. Hip should be stacked above the ankle.
5. Trailing leg should remain straight.
6. Extend the moving leg to push the body straight up into a standing position. Bring the trailing leg to meet the moving leg without pushing off the trailing leg.
7. Repeat for 10 lunges then switch to the opposite leg

Walking Knee Tuck

Target muscles:

- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Biceps femoris
- Semimembranosus
- Semitendinosus
- Gastrocnemius
- Soleus

Procedure:

1. Start in a standing position with feet shoulder-width apart.
2. Take one step forward in a normal walk pattern.
3. Reach down and grab the trailing knee.
4. Pull the trailing knee to the chest while simultaneously fully extending on the planted leg. Planted hip and knee should be extended with maximal plantar flexion.
5. Release the knee and swing the leg through into the next step.
6. Repeat for 20 tucks.

Walking Knee Over Hurdle

Target muscles:

- Psoas
- Iliacus
- Rectus abdominis
- Rectus femoris
- Vastus medialis
- Vastus lateralis
- Vastus intermedius
- Gluteus maximus
- Gluteus medius
- Gluteus minimus
- Adductors brevis
- Adductor longus
- Adductor magnus
- Gracilis
- Obliques
- Transverse abdominis

Procedure:

1. Set up 2 to 6 hurdles at an equal height that is just below hip height.
2. Stand in front of the first hurdle, throughout the exercise focus should remain on keeping the torso upright as well as the hips square and facing forward.
3. The lead leg will drive the knee up and towards the chest then plant on the opposite side of the hurdle.
4. The trailing leg will then pull through to the knee to chest position and plant on the ground next to the lead leg.
5. Clear all the hurdles then repeat switching the lead and trail legs.

Peripheral Neuromuscular Facilitation (PNF) Stretches

Hamstrings

Targeted muscles:

- Biceps femoris
- Semimembranosus
- Semitendinosus

Procedure:

1. Start by lying in a supine position with legs straight and feet dorsiflexed.
2. Hold both ends of a yoga strap, belt, or rope and wrap the object around the foot of the targeted leg.
3. Raise the targeted leg into hip flexion as far as comfortable while keeping the leg straight.
4. The opposite leg should remain flat on the floor.
5. Start the contract phase by contracting the hip extensors and pressing the targeted leg into the strap and holding for 8 seconds.
6. Relax the hamstrings by contracting the quadriceps and pulling the targeted leg into flexion, hold for 8 seconds.
7. Repeat 3 to 6 times as needed to relieve the hamstring of the targeted leg and then switch sides.

Deltoid

Targeted muscles:

- Anterior deltoid
- Medial deltoid
- Posterior deltoid
- Stretch will typically be felt through the pectoralis major and latissimus dorsi as well.

Procedure:

1. For PNF stretching of the deltoid, the user will start lying supine on the floor and will need the assistance of a dowel rod, broom, or other long and light-weight object.
2. The arm intended to be stretched should start completely straight and pointing towards the ceiling.
3. Hold the rod with the non-stretching arm and place the end of the rod in the palm of the arm to be stretched.
4. Gently push the stretching arm overhead to a comfortable maximal range of motion.
5. Hold for 8 seconds.
6. Then contract stretching arm into the rod by trying to perform a pullover while resisting with the opposite limb.
7. Hold for 8 seconds.
8. Repeat the overhead stretch and pullover contract 3-5 times.
9. Switch arms and repeat on the opposite side.

Latissimus Dorsi

Targeted muscles:

- Latissimus dorsi
- Stretch will be felt along the serratus anterior as well.

Procedure:

PNF stretching of the latissimus dorsi will start on the knees and require the use of a tall bench or box.

1. Place both hands with straight arms on the box then sit back towards the heels trying to get maximal extension through the torso.
2. Hold the end position for 8 seconds.
3. Contract the latissimus dorsi by trying to push downward the hands through the box towards the floor.

4. Hold contraction for 8 seconds then relax.
5. Repeat stretch and contract phases 3-5 times.

Summary

Flexibility, the ability to take joints through a full range of motions safely, is a key aspect of overall fitness that most clients will need to spend some time developing. While different intrinsic factors can influence flexibility such as age, weight, and joint structure, fitness professionals can still help their clients make improvements by using the correct type of stretching and warm-ups to both prepare people for exercise movements and increase their overall ranges of motion for daily life.

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Chapter 14

Adaptations to Resistance Training

Travis McKinney, MS

Introduction

The body undergoes many different beneficial adaptations in response to prolonged resistance exercise training. For general fitness clients, these adaptations are typically the primary reason for including resistance training as a pillar of fitness.

Fitness professionals must understand the various adaptations and processes to effectively plan, program, and adjust programs, as well as explain the rationale to clients.

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General Adaptation Syndrome

General Adaptation Syndrome is a theory developed by Dr. Hans Selye in the early-to-mid 20th century. Selye is known to be the first researcher to use the term "stress" in reference to changes in the body after a stimulus is applied.[1] Stress is defined as a "non-specific response of the body to any demand."

Through various experiments, Selye concluded that his newly coined term of General Adaptation Syndrome is "a generalized effort of the organism to adapt itself to new conditions."

In 1950, Selye publicly adopted the position that "stress is the interaction between damage and defense. It is the rate of wear and tear caused by life." The term stressor was coined soon after, which refers to anything that can produce both stress and specific action.

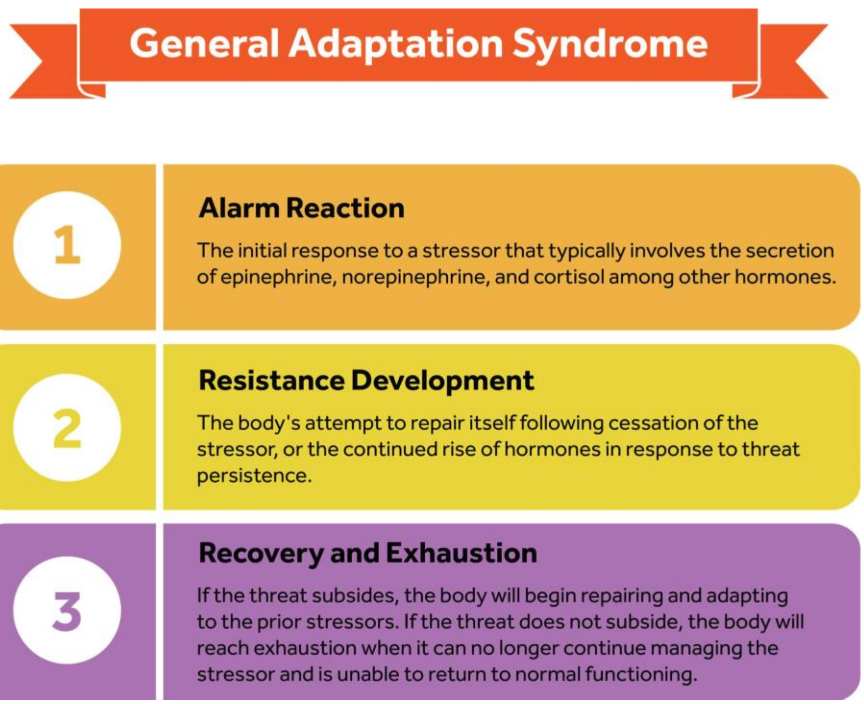
As knowledge of stress and physiological adaptations continued to develop, so did the understanding of GAS. It was repeatedly shown that regardless of the stressor being applied, the physiological processes appeared to follow a similar pattern.

The GAS was later defined in three separate stages:

- Alarm Reaction
- Resistance Development
- Exhaustion

The alarm phase was the initial response to the shock that occurred to the body which elicited a resistance, or series of metabolic defenses against the initial stimuli. If the stimuli persisted, exhaustion would occur which would lead to death in extreme cases.

Note: original studies tunneled towards physical stressors such as pain or discomfort. It is now known that emotional stressors may trigger similar physiological responses. Stressors may include a job loss, break up, financial struggles, poor grades, or embarrassment. It does not require extreme temperatures or surgeries to trigger GAS. Selye was adamant that irrespective of the nature or quantity of the stressor, the physiological mechanism of response for any living organism always remained the same.[2]



Alarm Reaction

The **Alarm Reaction** (AR) is the first stage of GAS when an organism faces a stressor. Selye compared it similar to the fight or flight reaction, but the AR allowed for chronic responses leading towards further responses.

Biological reactions during alarm reaction typically include secretion through the adrenal glands (specifically the adrenal medulla), most commonly are epinephrine and norepinephrine, however, cortisol is upregulated by the presence of epinephrine.

Other hormones affected include estrogen, testosterone, dopamine and serotonin.[3]

Cortisol is known as the “stress hormone.” It is present in high concentrations when the body undergoes stressful situations. When cortisol is upregulated, the response includes an increase of blood pressure, blood glucose, and the immune system is suppressed.[4]

Epinephrine and norepinephrine are responsible for acceleration of heart and lung activity, inhibition of digestion, constriction of many blood vessels to organs, release of lipids and glucose for energy use, dilation of muscular vessels, dilation of pupils, hearing loss, tunnel vision and shaking, for an inconclusive list.[5]

Remember, the primary intent behind these hormones is to survive when faced with imminent danger, therefore bodily functions that are unnecessary for short term survival (such as digestion, urination and reproduction) are inhibited until the threat is gone.

Resistance Development

Resistance Development (RD) is the second stage of Selye's GAS model. This stage is noted by the body's attempt to repair itself after being shocked with an influx of stress through the AR phase. There are two paths the body can take in this stage and it depends on the environment of the individual.

In the first option, hormone concentrations return to homeostatic levels if the threat has subsided. If the threat persists then the stress hormones will continue to rise, thus increasing the effects of those hormones. This means digestion continues to slow, vessels to organs continue to contract, vessels to muscles stay dilated, and heart rate and blood pressure stay elevated.

Recovery and Exhaustion

Similar to resistance development, the third and final stage may be split depending on if the threat is prominent or not. If the threat is not prominent, then recovery begins. If it is still prominent, by stage three the organism will be reaching exhaustion.

Recovery will begin when the source of stress has subsided, but the previous stages have already prepared the body to recover. The changes in hormone status from the previous two stages have upregulated the amount of glucose, lipids, and amino acids that are free floating within the bloodstream which provide a more readily available source of nutrients. Since the body is reducing stress levels, the free-floating nutrients may be utilized for recovery and anabolic reactions.[7]

Exhaustion can be observed when a body has worked itself until it cannot continue further. This is when energy stores are reaching near depletion of their usable stores. The body is demonstrating the inability to return to a status of normal functioning.

Personal trainers and fitness professionals must be aware of the overall implication of the General Adaptation Syndrome. Clients must understand the importance of taking days off to actually see progress. Coaches must understand how to program the proper amount of exercise to elicit the body adaptations without pushing the client past the point of exhaustion in the General Adaptation Syndrome.

Stimulus-Fatigue-Recovery-Adaptation Theory

The Stimulus-fatigue-recovery-adaptation theory suggests that exercise triggers both fatigue and adaptation. The magnitude of both depends upon the magnitude of the stimulus. Therefore, the longer or more intense the training session, the greater amount of recovery time is needed until full recovery. As the client recovers and adapts to the previous training stimulus, the more fatigue will dissipate.

If the client waits too long to train again, the body will begins to detrain and it loses the adaptations. With proper programming, full recovery usually occurs before detraining begins. Then, clients can train continuously with full or near full recovery in between training stimuli for extended periods of time. This is especially true for novel exercisers, as their total workloads during sessions are typically low.

Fitness-Fatigue Paradigm

Another way to consider the interaction between stimulus and fatigue is the fitness-fatigue paradigm. If training induces both adaptation (fitness) and fatigue, then the sum of the two can be considered the primary driver of a client's performance referred to as "preparedness.[6]"

When training loads are high, fitness rises; however, so does fatigue. Therefore, preparedness is relatively low. This is also true if training loads are very low. Fitness is low, but so is fatigue. Thus, a balance must be struck, via a structured periodized program, which will dissipate fatigue but maintain a high level of fitness.

Accumulation vs Deloading vs Maintenance

Accumulation, deloading, and maintenance are the programmatic applications of GAS and the other physiological theories behind periodized training.

Accumulation

Periods of hard training, wherein adaptations are stimulated, and fatigue is accrued is referred to as accumulation. The number of these sessions that an individual can perform continuously (i.e. the weeks of hard training) without a period of recovery will vary based on a variety of factors such as training age (experience with exercise), chronological age, dietary status, sleep quality, stress levels, and training intensity. However, even under optimal conditions, all clients eventually reach a point where training stagnates. This is the time to deload.

Deloading

A deload is a period of reduced training volume and intensity to allow the body to recover and for the adaptative mechanisms to resensitize the body to training. Deloads typically last one week but must vary based on clients' needs.

Programming a deload can often be challenging for trainers, especially when working with new clients. There are two variables to consider: the length of deload and the degree to which normal training volume and intensity are reduced.

Length of Deload

A week has become a standard deload period for many exercisers across a broad spectrum of training and chronological age. This allows for mental recovery, as well as physiological recovery of the muscle tissues and joints. However, shorter periods can be employed for clients with limited training experience, as their exercise-induced muscle damage is lower than intermediate or advanced clients. Also, older clients may require longer deload periods as their recovery cycle is often longer. Research is still underway to quantify the optimal range of deload duration, however anecdotal evidence suggests that no fewer than 3 days and no longer than 2 weeks are best.

Volume and Intensity Reduction

The second variable of the deload: training volume and intensity, has greater variation. The goal of the deload is to reduce training stress; this can be accomplished by reducing the load or volume of training, or both. A common strategy is to maintain the training load and reduce the volume by half. However, if joint stress is an issue, consider reducing the load by half or one third should also be considered.[3] In either case, as long as the goal (reducing training stress) is met, any strategy can be effective. On the other hand, a week of complete rest, with no training, is not recommended. It is well established by research that mild amounts of physical activity actually facilitate recovery; therefore, some level of training is better than none.

Maintenance

Even with regular deloading periods at the end of mesocycles, occasional periods of prolonged active recovery, called maintenance cycles, are suggested. Months of prolonged training, even properly programmed with deloads, lead to significant wear and tear on the joints and substantial loss of psychological arousal for training. Maintenance cycles can solve these problems before manifest.

During maintenance clients should train very little, only enough to maintain their current level of fitness. The focus during this 3—4 week cycle is twofold: mental and physical recovery. Clients should continue to be physically active and engaging in daily mobility and warm-up activities. Clients can also engage in several one to two training sessions per week but intensity and volume should be very low.

The relationship between accumulation, deload, and maintenance is cyclical. Clients should engage in prolonged periods of accumulation, concluding with deloads as needed. When deloads are no longer effective at reducing fatigue or when overuse injuries begin to occur, a maintenance phase is necessary.

SAID Principle

The SAID acronym stands for Specific Adaptations to Imposed Demands and applies the concepts of the General Adaptation Syndrome to reach a given goal.

For a simple example, if an individual is trying to run a marathon, most of their training will likely be surrounded by endurance-based activities.

A client who is training to complete a marathon will not benefit from max effort bench press training during their preparation, because the adaptation for a heavy bench press does not improve lower body endurance.

However, a competitive powerlifter who is preparing for a competition would utilize a heavy bench press during their training since the one-repetition max bench press is relevant to their sport.

The powerlifter will likely not be running in a way that raises aerobic capacity, as a strategy to prepare for a bench press contest. The concept of imposing demands similar to that of the goal that the individual is trying to achieve is utilizing the SAID Principle.

Progressive Adaptations to Resistance Training

During the training process, there are two ways to induce an adaptation. One is to increase the training load (intensity, volume), while continuing to employ the same drill, for example, endurance running, where the length of the run increases.

The other is to change the drill, provided that the exercise is new, and the athlete is not accustomed to it. If an athlete uses a standard exercise with the same training load over a very long time, there will be no additional adaptations and the level of physical fitness will not substantially change."[12]

When this concept is applied to resistance training, the amount of weight being lifted needs to be greater than the normal amount that the person would normally lift, if they want to continuously see progress. The weight lifted could increase through more total repetitions (between all sets and repetitions), or through an absolute load (90lbs instead of 80lbs).

If the athlete continues with the same volume scheme each time they perform the exercise, such as 3x10x80lbs every week on the exact same movement, they will eventually stop progressing and become stagnant. Variables that can be changed include the weights, repetitions, sets, rest periods, frequency, and total volume. Additionally, using different variations of movements or types of exercises is another way to change the stimulus and promote further adaptations.

Skeletal muscle adaptations are achieved through training programs, with the intent to achieve a specific goal. In the context of resistance training, the main adaptations are muscular endurance, hypertrophy, strength, and power.

While each of these adaptations has crossover in terms of their effects and benefits, they each represent distinct changes in the muscle fibers that must be specifically targeted with appropriate workout programming depending on the client's goal.

Muscular Endurance

Athletes who specialize in muscular endurance largely participate in exercises that contain a relatively light-to-moderate resistance, but do not greatly activate the cardiorespiratory system.

Muscular endurance exercises can be split between maximum repetitions within a set time, such as 60-second max repetition push up drills, or they can involve a max time that a person can maintain a specific posture or pace of repetitions, such as in a two-minute plank.

Remember that absolute strength is not the goal and it's been shown that when using weight below 25% of a one-repetition max effort attempt, it is impossible to predict the number of repetitions an athlete could complete.

Strength and endurance are not closely related. Athletes who train with an endurance intent will typically work within the 12-25 repetition range, or even a greater number. These athletes should keep short rest periods in an attempt to increase their rate of lactate buffering.

Maintaining rest intervals between 30-60 seconds, or approximately a 1:1 ratio of work to rest, will create an environment that increases blood lactate levels. Clients training under this condition will more efficient at buffering blood lactate so the individual has an increased ability to sustain repeated moderate to maximal muscle contractions over a longer period of time.[13]

Hypertrophy

Hypertrophy at its root is an increase in the size of the muscle cells, resulting in an increase in muscle cross-section area and volume.

For most general fitness clients, especially those who are deconditioned, improved muscle mass is generally a beneficial adaptation in terms of health outcomes and obtaining a more muscular appearance.

During resistance training, mechanical and metabolic stress results in muscle damage and the subsequent hormonal responses that stimulate hypertrophy.

Hypertrophy generally occurs due to an increase in the size of existing muscle fibers via the addition of myofibrils and increases in actin and myosin and other muscle cell components. The hormones secreted in response to resistance training play a major role in driving muscular hypertrophy.

Clients who seek to maximize muscle hypertrophy should use weights equivalent to a 5-12 repetition maximum effort attempt. Clients should perform multiple sets while leaving 1-2 repetitions in reserve and resting between 1-2 minutes to maximize hypertrophy.[12]

Strength

In the context of fitness training, strength is the ability of the body to exert force via muscular contraction. The purest measure of absolute strength on a given movement or exercise is the 1-repetition maximum. Resistance training activities for improvements in strength typically utilize a lower number of repetitions, often between 1 to 5, high levels of resistance, and longer rest periods.

When individuals train towards the goal of maximal strength, adaptations occur within the body to accommodate for the increased stimuli and demands being placed. These adaptations change the body and increase its ability to exert force, translating into greater performance on maximal strength activities, as well as the associated beneficial biological adaptations.

Changes within the body that contribute to an increase in strength have to do with both the physical side of the body and the neural side of the body such as motor recruitment, covered in the nervous system chapter.

While strength adaptations do not occur solely as a result of hypertrophy, increased muscle cross-section results in greater force production capabilities.

When discussing the physical adaptations of hypertrophy, the most noticeable is the increase in cross-sectional area (CSA) of the muscle fibers and an increase in sarcomere volume.[14]

As discussed in the skeletal system chapter, bone mineral density, and subsequent bone mass increase as a progressive response to resistance training. This increases the ability of the skeletal system to withstand external resistance and resist bone fractures.[16]

Tendons are another site of adaptation to resistance training. Researchers have found that just 12 weeks of resistance training improved tendon stiffness, reflecting greater tendon strength.[17]

In the long run, increased strength depends on increasing the size of the muscle fibers, the ability of the nervous system to fully recruit fibers, and the density and strength of the skeletal system. For this reason, strength-focused periodization plans usually include hypertrophy-focused training blocks as well as higher intensity, lower repetition strength blocks to drive neural adaptations.

Similarly, general fitness clients benefit from cycling between programs focused on muscular endurance, hypertrophy, and strength to elicit the full array of beneficial adaptations to resistance training. How to structure and cycle workout programs is covered in more depth in the chapter on periodization.

Power

Power in the absolute sense is a measurement of the rate of energy production of a given activity. In the context of physical fitness adaptations, power refers to the ability to create maximal force within minimal time.[12] As such, the rate of force production matters in power considerations alongside the maximum force exerted. To increase the rate of force development, which is the primary goal for power training, an individual must train in a manner that increases their ability to move faster.

Power exercises include explosive lifts such as those in Olympic weightlifting, plyometric activities such as jumping, and maximal effort sprints using traditional aerobic modalities such as running sprints, cycling, or rowing using short working periods and long rest periods to ensure sufficient effort on each set.

Most strength-focused training exercises also improve power, especially in novice athletes and the deconditioned. Since power depends on both speed of movement and the amount of resistance, increasing the resistance while maintaining the same speed of movement reflects improved power. As the client gains training experience, continued power focused adaptations will require specific focus on movement speed.

In the context of aerobic training, power is typically expressed as watts and is used as a way to measure the absolute output. Activities such as cycling make measuring watts straightforward compared to running or swimming. While this use of "power" is correct from a physics standpoint, when it comes to resistance training, power training primarily refers to anaerobic exercises performed quickly and explosively.

In the context of personal fitness training, power training can include a variety of bodyweight and equipment-based training methods. Jump squats, Olympic lifting, medicine ball throws, and any movements performed quickly and explosively are all power training exercises commonly used to elicit improvements in peak power.

The adaptations to power development are comparable to that of strength adaptations. In a study by MacDougall that was published in the *Journal of Applied Physiology*, they observed the physiological differences in 12 healthy men who participated in a sprint style program on a cycle ergometer.[20] It is important to understand that these are not elite athletes.

These 12 healthy men trained with multiple bouts of 30-second sprints for 7 weeks. On week 1 the subjects began with 3 sessions per week and performed 3 – 30 second sprints on week 1 and increased to 10 – 30 second sprints during week 7. Between each bout was a 4 minute rest period for the first 4 weeks. In weeks 5-7, they decreased their rest periods by 30s each week.

Significant results from the study showed an increase in 12% mean total power output after the 4th bout of sprints and approximately a 25% increase in peak power output among the participants when comparing their 7-week differences. They demonstrated a 7% increase in VO_2 max, a 49% increase in phosphocreatine kinase (PFK) activity, 56% increase in hexokinase activity and 36% increase in citrate synthase (CS) activity.

Overall, this demonstrates that clients can experience significant beneficial results from a variety of strength and power training modalities.

Fitness professionals should take note that adaptations to resistance training occur primarily on a spectrum where certain adaptations are more heavily favored within certain repetition, intensity, and movement speed ranges as opposed to a hard cutoff point for each adaptation.

For example, training with 3-5 repetitions using appropriate intensity will result in some hypertrophy alongside the strength adaptation. Hypertrophy would be increased between 8-12 repetitions, while still eliciting some strength gains. Finally, pushing past the 12 repetition range will cause an increasing shift away from hypertrophy and towards muscular endurance.

Sedentary, deconditioned clients will see the greatest across-the-board adaptations using a variety of repetition ranges. As training experience increases, training programs must be specific to the desired adaptations to ensure progress.

Summary

Considering the adaptations caused by different stressors on the body, fitness professionals should be monitoring the system fatigue in clients throughout a training cycle, as well as choosing specific exercises to target the changes clients are looking for through an exercise program.

Hypertrophy, endurance, strength, and power all require different loads, rep ranges, rest periods, and exercises, while blocks of accumulation, deloading, and maintenance may be required to achieve optimal results based on overall recoverability across a training cycle.

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Chapter 15

Resistance Training Protocols and Systems

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Introduction

Fitness professionals must have in-depth knowledge of the various training protocols and systems for improving strength and fitness. Professionals should be particularly familiar with the equipment in their facility, and the modalities they plan to use with their clients.

Each modality has its pros and cons. While certain populations may benefit from the proper use of these styles more than others, nearly all populations can find an intelligent use for each modality and receive positive results. Two of the fundamental parameters discussed here are set training and exercise implements.

Single Set

Single set training utilizes one set per exercise before moving on to another movement. For example, if an individual performed one set of 20 repetitions and moved on to another exercise, that would be considered a single set-style of training.

Single sets are most appropriate for novice clients and can be effective at inducing muscular development.[24] Additionally, single set training can be used as a method to test muscular endurance and anaerobic capacity.[22]

Clients who have already completed several months of resistance training will need to add multiple sets or other means of increasing volume in order to see continued results.

Multiple Sets

Multiple set training calls for performing more than 1 set of an exercise in an individual workout. Multiple set training is one of the most used methods when programming resistance workouts in order to create the best muscular adaptations. For example, performing three sets of ten (3×10) for hypertrophy or five sets of five (5×5) for strength would constitute examples of multiple sets.

Research has consistently shown multiple set training to be superior to single set training when it comes to strength and hypertrophy adaptations.[25, 26]

Pyramid Sets

Pyramid sets are a common method used by old-school bodybuilders and strength athletes. This is a style where the weights increase with each set. Typically, as a heavier weight is being used, the number of repetitions performed will decrease. However, this concept follows the increase in the weight to reach the "peak" of the pyramid and then back down.

An example of Pyramid Sets may include (reps x % of 1RM):

- 10×50%
- 8×60%
- 6×70%
- 4×80%
- 2×90%
- **1×100% (top of pyramid)**
- 2×90%
- 4×80%
- 6×70%
- 8×60%
- 10×50%

Superset

A superset, commonly spelled using one word, is when two exercises are performed back to back. "Supersetting" exercises is a useful programming method for a multitude of different reasons. Performing supersets reduces the total time to complete a given number of sets, making it an effective way to reduce workout time and/or increase workout volume and intensity without increasing total time.

The specific training goal will determine the exact superset structure. For strength focused training, opposing or unrelated muscle groups can be exercised in quick succession followed by a moderate rest period between each superset. For example, performing lat pulldowns followed by overhead presses.

As the latissimus dorsi muscles recover from the set of pullups, the deltoids are performing their work on the overhead press. The deltoids then rest during the full rest period and during the pull up set, before being tasked with the second set of overhead presses.

Supersets can also be performed using the same muscle group twice in a row with a different exercise, which increases the volume performed by that muscle group. Due to the increased fatigue and subsequent decrease in total weight required, supersetting the same muscle group is most appropriate for muscular endurance and hypertrophy.

For example, a person who performs hamstring curls could then follow up with a set of 45-degree back extensions. By performing the two exercises back to back, the hamstring muscles are being worked in quick succession and by targeting both of its purposes, flexion at the knee and torso extension at the hip.

Drop Set

Drop sets are a technique that involves performing a relatively heavy set, then immediately removing some of the weight and performing another set.

For example, a client performing drop sets on the bench press exercise might perform a set using 80% of their 1-repetition maximum and then immediately reduce the weight to 65% 1RM and complete the next set. The client repeats the process without resting in between sets until the target number of drop sets has been reached.

Drop sets are an excellent choice to promote quick exhaustion, hypertrophy and to save time as little to no rest periods are used. Some lifters will utilize a drop set as a 'burnout', which would be performing as many repetitions as possible (AMRAP) on the very last set of the exercise.

The client could perform a normal 3×10 multiple set method at 75% 1RM on the bench press and then perform maximal repetitions to failure on a final set, followed by decreasing the weight to 50% and again performing maximum repetitions. They could then continue by reducing the weight after the client reaches muscular failure on each set and move on to the next.

Circuit Training

Circuit training involves performing a single set of one exercise followed by a single set of a different exercise and continuing on through a series of exercises to complete the full circuit. At the end of the circuit, the exerciser would then go back and repeat the circuit if performing another set.

Circuit training is often constructed using a set time performing each exercise with a submaximal resistance level. A client could perform 30 seconds of goblet squats using 20% 1RM, performing them as quickly as possible, followed by a quick transition to 30 seconds of V-ups, and continuing on through a variety of exercises.

Circuit training can improve cardiovascular development, anaerobic capacity, and improve body composition, depending on the programming in the circuit.[27, 28]

Peripheral Heart Action (PHA)

Peripheral heart action (PHA) is similar to circuit training and involves performing a series of exercises in quick succession. Rather than allowing for any exercises in random order, PHA requires the lifter to alternate from upper body to lower body movements.

The alternation between upper to lower body movements in quick succession causes a dramatic increase in cardiovascular activity. When exercises are being performed, an influx of blood is delivered to that body part which has a higher demand for oxygen, energy, and nutrients.

When the movements are alternating between upper and lower body, that flux of blood is rotating between whichever side of the body is in highest demand, while the previous section of the body is still recovering.

When performed with high intensity, PHA style training can burn calories at a rapid rate.

Vertical Loading

A vertical loading routine will utilize multiple supersets in a circuit-like fashion. The intent behind this style of routine is to order the exercises by the proximity of the muscles that they work. For example, a lifter may perform shrugs, dumbbell side raises, dumbbell rows and situps all in succession to one another, resting in between sets if the goal is hypertrophy or strength.

When the last exercise is completed, repeat the same series of exercises until the desired number of sets is completed. The intent behind this style of routine is to provide more rest for a muscle group while other muscle groups are being worked on compared to performing back-to-back sets of the same exercises.

In the above example, the athlete would be rotating between the muscles of the trapezius, deltoids, latissimus dorsi, and abdominals prior to restarting the circuit at trapezius or shrugs again.

Horizontal Loading

Horizontal loading is the opposite of vertical loading. While vertical loading rotates the muscles being worked on each set, horizontal loading ensures that all prescribed sets of an exercise are completed prior to moving on to another exercise.

This is used in conjunction with the multiple sets method and is most commonly utilized by strength athletes. Remember that the multiple sets method is simply performing more than one set on any exercise, whereas horizontal loading specifically prevents the utilization of supersets.

Resistance Training Protocols

Single Sets
Performing one set of an exercise per workout in the training plan.

Multiple Sets
Performing two or more sets of an exercise per workout in the training plan.

Pyramid Sets
Performing two or more sets of the same exercise while increasing the weight on each set, until a target maximum weight for the exercise is reached at the "top" of the pyramid set.

Supersets
Performing one set of two or more exercises back-to-back with little or no rest in between. Rest is taken after all exercises in the superset have been performed once, at which point additional rounds of supersets can be performed.

Drop Set
Performing a heavier set of an exercise then immediately reducing the weight and performing an additional set.

Circuit Training
Performing a single set of one exercise, usually for time, followed by a single set of another exercise, repeated for each exercise on the circuit. Rest periods can be included between each exercise, or the circuit can be performed as a superset with no rest between exercises.

Peripheral Heart Action
A style of circuit training that alternates upper and lower body exercises.

Vertical Loading
Structuring the training session as one large superset, completing one set of each exercise until all exercises have been completed, then repeated from the beginning until the desired number of sets have been completed.

Horizontal Loading
Structuring the training session to complete multiple sets of a single exercise until all sets have been completed before moving on to the next exercise.

Split Routine
Structuring individual training sessions around specific body parts or muscle groups.

Resistance Training Implements

Bodyweight / Calisthenics

Using the weight of one's own body as resistance for exercises is called calisthenics. Many people refer to this style of exercise as simply 'bodyweight exercise,' but the two are synonymous and can be used interchangeably depending on the populations within the conversation.

Bodyweight-style exercises have been a favorite of an incredibly wide variety of populations due to the convenience of performing the movements. To achieve an effective bodyweight workout, one can perform many exercises within the comforts of their own home or outside on a playground, especially if there is access to an overhead pullup bar of some variety.

Bodyweight training encompasses straightforward movements such as glute bridges, push-ups, pull-ups, and squats as well as advanced calisthenics such as handstand pushups, high-intensity plyometrics, and gymnastic-style exercises.

Nearly every population can benefit from bodyweight exercises. The intensity of bodyweight training depends on the exercises performed as well as the individual body mass of the person performing the exercise. Bodyweight movements are progressively more difficult if the weight of the body is heavier.

Bodyweight exercises are common within rehab clinics. Oftentimes these movements are used to recover from an injury or preserve quality of life. An elderly individual may perform sets of 'squats' by sitting in a chair and standing back up without the use of their hands. Another individual recovering from an ankle injury may perform calf raises in an effort to rebuild mobility and coordination.

These movements can also be regressed by using bands to help take off some of the load on the body, or with added weight to increase the difficulty of the movements.

Barbell

Barbells are a mainstay of most resistance training equipment setups. A normal bar is referred to as a "power bar" and weighs a standard 45 pounds or 20 kilograms (44.2 pounds). Entire training programs can be created by using a straight bar as nearly every muscle in the body can be activated with a properly formulated barbell routine. There are aspects of resistance training that can be accomplished more effectively by using other methods of training, but a straight bar is the bread and butter for many athletes of all levels.

Exercises such as the squat, bench press, deadlift, snatch, clean and jerk, overhead press and curls are staples in most strength training regiments, and they all utilize the straight bar. It is common to have strength programs centered around the squat, bench press, deadlift, and overhead press where lifters workout several times per week, performing one of those movements at the start of each workout.

A straight bar has many inherent advantages and disadvantages. Because weight is directly loaded to the bar it is easy to calculate how much resistance is being used and easy to increase the load by small increments over time.

One of the major disadvantages to utilizing a straight bar only in training is that over extended periods of time, barbell training can result in the development of muscle imbalances if coaches do not properly program a variety of movements using other equipment or even just other styles of barbell.

There are many styles of barbells to use in a training program. Note that for beginner, intermediate, and even advanced clients, most standard barbells are sufficient when included in a balanced training program, and specialty bars for each lift are not necessary until the weight being lifted is substantially beyond the capabilities of most fitness clients. However, it is still important for personal trainers to have knowledge of the types of barbells given their prevalence in strength and conditioning programs.

A non-exhaustive list of bars to utilize in training includes:

- the squat bar
- bench press bar
- deadlift bar
- Olympic bar
- safety squat bar (Hatfield bar)
- cambered bar
- bow bar
- multi grip bar

The squat, bench press, and deadlift bars are specialized for elite level powerlifters who require bars that accommodate their lifts. Most gyms are equipped with a standard barbell typically weighing 45 pounds without added weight, with moderate knurling.

Squat Bar

A squat bar is thicker and heavier than a 45 pound bar, with a larger loading sleeve. This allows the bar to hold more plates than a standard bar and reduces the amount of whip, or vibrations that occur within the bar.

When lifters approach heavy weights, such as 700 pounds or greater, standard bars tend to flex and bend uncontrollably which can be hazardous for stability and can cause serious injuries. Bars must be capable of handling the weights that they are put through. Squat bars tend to weigh between 55 to 65 pounds.

Bench Press Bar

Bench press bars are a medium between a power bar and a squat bar. They can maintain rigidity with more weight than a power bar, they are thinner than a squat bar, and they have more loading area on the sleeve than a power bar. The bench press bar isn't necessary until the lifter is performing over 800 pounds.

Due to the contact points of the hands on the bar being wider during a bench press than the shoulders when they support the bar during the squat, bars tend to flex less under equivalent weight during a bench press as opposed to a squat. A bench press bar typically weighs between 50 to 55 pounds.

Deadlift Bar

Deadlift bars are the opposite to the previous two bars. Deadlifts bars are made slightly longer and thinner than a standard power bar. They weigh 45 pounds and the intent of them is to flex more than normal off the floor, while being easier to hold onto.

If the bar flexes one inch before the end plates break from the floor, that means the range of motion for the deadlift has decreased by one inch. Utilizing this bar is most helpful for individuals with an ultra-wide sumo deadlift stance, those with very small hands and people with a short range of motion to begin with.

Note: Specialized squat, bench press and deadlift bars are only necessary for elite level powerlifters.

Olympic Bar

An Olympic bar has specs modified for Olympic weightlifting, which consists of the snatch and the clean and jerk. This bar typically has smaller and softer knurling which reduces the likelihood of the skin on the thumbs ripping when forcefully pulling with a hook grip.

Olympics bars do not have a center knurling on them. This smoothness allows for the bar to hit the thighs during the high-pull portion of the Olympic lifts, without it snagging on the lifter's clothing. The sleeves of an Olympic bar use 'needle bearings' which when well-greased, allows the sleeves to spin several seconds longer than a typical power bar – which may not spin at all sometimes.

Lastly, Olympic bars are made with lower tensile strength to allow the bar to flex or whip, much like a deadlift bar.

Safety Squat Bar

The safety squat bar (SSB) was originally called the "Hatfield Bar" after Dr. Fred Hatfield who designed the first model. This bar is one that should be utilized by coaches and trainers as their default, prioritizing it beyond a straight bar for squats.

The SSB is denoted by large, foam pads that sit atop the shoulders and behind the neck. It has handles that jet forward and two forward facing pads are diagonally facing downward. The bar has a slight camber to it and the slides sit forward rather than straight down.

The diagonal angle of the handles causes the pads to press into the upper chest of the lifter while the angle of the sleeves shifts the center of gravity of the bar forward. This combination encourages the lifter to round their upper back.

The lifter must maintain an upright posture throughout this movement. The advantages to squatting with the SSB is that maintaining the upright posture uses the muscles of the upper back to a much greater degree than a straight bar does. The pads of the SSB sit the bar higher on the shoulders which shifts the point on the lifter with the most structural stress to be on the upper back, as opposed to the lower back with a straight bar.

Lastly and arguably most significantly, the SSB allows lifters to squat without applying stress to their shoulders or elbows like a straight bar does. Consider replacing straight bar squats with SSB squats. This bar can be used by anyone who is capable of performing a weighted squat.

Cambered Bar

A cambered bar is rarer to find in gyms than a SSB is. The cambered bar is identified by two vertical bars that drop down from the horizontal centerpiece. The lowered center of gravity means that this bar stimulates the muscles of the lower back much harder than other bars would.

When using the cambered bar, the plates sway forward and backwards which causes a sense of instability. This instability forces the lifter to practice proper bracing techniques otherwise the risk of injury heightens significantly. Lastly, since this bar has vertical uprights along the sides of it, the lifter may place their hands lower on the uprights to reduce stress on the shoulder joints.

Bow Bar

The bow bar is most commonly called a "Buffalo Bar" named after the first company to create a curved bar. This bar functions similarly to a straight bar, but has a curve to it. The curve allows a gradual reduction in height from the peak of the bar, down to the sleeves, and typically has a 4 inch difference in height.

The bow bar is used to mimic a straight bar, but reduce tension on the shoulders. Many lifters with shoulder mobility issues due to injuries, age or muscle mass will squat with a bow bar instead of a straight bar.

Dumbbells

Dumbbells (DBs) are weights in the form of short handles with added weight attached to either side. Dumbbells are arguably the most versatile piece of equipment within a gym.

They are predominantly used for work that requires weight to be held in a single hand but exceptions can be made for exercises such as weighted sit ups or pull ups, where the DB is held between the feet.

Common exercises with DBs are DB press, DB rows, DB Romanian deadlifts, DB side raises, DB triceps extensions, and DB curls. There are thousands of exercises that can be performed with DBs. The largest benefit of using DBs comes from the ability to work muscles unilaterally. DBs are a consistent tool to utilize for gym goers of all ages and ability levels.

Machines

Machines are a standard class of equipment in any facility that promotes exercise. Machines may be pin loaded, or plate loaded. Pin-loaded machines have stacks of weights with a hole in the center, both a vertical hole and a horizontal hole.

A post with horizontal holes is stuck through the center of the weight stack and the holes of that post align with each hole of the plates in the stack. When a pin is pushed through a plate, it locks into the center post and the lifter may move the selected amount of weight.

A plate loaded machine is much simpler in design. Rather than moving a predetermined amount of weight from a convenient stack, the machine has empty sleeves where plates may be put on to. The number of plates on the sleeve will determine the amount of weight being moved.

There are thousands of different variations of machines to work all the different muscle groups in the human body and it is impossible to cover them all.

The key constant between every machine is that the machines are built onto a fixed track. There is one motion that can be used with that machine and when under proper working order, the machines will not deviate from the predetermined track. This decreases the stabilization requirements for the movements compared to free-weight exercises.

The biggest notable exception to the fixed motion are cable machines, which offer some instability as well as a constant angle of resistance across the full range of motion. Common exercises on the cable machine include lat pulldowns, triceps extensions, face pulls, and cable curls.

Alternative Implements

Alternative implements are effectively any device or tool used to provide resistance for a training stimulus that falls outside the traditionally used bodybuilding tools such as barbells, dumbbells, and weight machines.

Nevertheless, alternative implements of a variety of types are becoming increasingly common in commercial gyms due to their popularity and versatility towards a variety of fitness goals.

Kettlebells

Kettlebells are incredibly versatile and useful to a wide variety of populations. Some athletes choose to compete in kettlebell competitions which perform various kettlebell based movements for maximum repetitions within a set time typically.

Kettlebells may be found in 5-70 pounds typically, but some retailers carry up to 200 pound kettlebells. The most popular movement is the "kettlebell swing" which is similar to the initial motion in a Romanian deadlift. The athlete adopts a shoulder or wider width stance, holds the kettlebell with both hands, and gets a swinging start.

Once a small amount of momentum has occurred, the athlete forcefully pushes their hips back, and then extends them forward while relaxing the shoulder joint. The force from the hips at the catch, or bottom position of the kettlebell swing will carry the kettlebell to shoulder height. When performed correctly, kettlebell swings provide a plyometric-type stimulus for the posterior chain.

Heavy kettlebell swings can build strength, power, and explosiveness through the glutes, hips and hamstring muscles. Other common exercises with kettlebells include overhead press, overhead squats, suitcase carries, Turkish get ups, and overhead throws if performed on grass.

Strongman's Yoke

The yoke is a standard strongman implement. Yokes look like old style squat stands with a bar welded in the center. Weights are placed on sleeves that stick vertically on the base of all four corners. The athlete assumes an athletic position under the center of the yoke, braces properly and squats the yoke off the ground. The athlete will carry the yoke a predetermined distance. The instability and bulk of the yoke makes it awkward to carry.

With light weights the yoke may be used with a normal, healthy adult population as it promotes abdominal stability and mobility. Due to the swinging of the implement, the yoke can be potentially dangerous to the lumbar spine of an ill-prepared individual.

Farmer's Handles

Farmer's handles are becoming more common within the general population, but especially popular within tactical athletes. Farmer's handles are a pair of handles that allows plates to be loaded on both the front and back side of the implement.

The handle only has enough room to be gripped with one hand. The athlete carries both handles, with equal load on either side, and hastily walks the handles a predetermined distance. This exercise may be used with the general population with light weights but is especially useful for competitive athletes of nearly all disciplines.

The farmer's carry promotes trunk stability, grip strength and mobility. Consider using a farmer's carry for general preparedness or conditioning with a variety of athletes.

Logs

Logs are a tool that are nearly exclusively used by strongman athletes. A log can be made from a metal mold or cut from real wood. It is an implement that typically ranges from 8-12" in diameter and is intended for the log clean and overhead press. There are large holes carved into it where the handles are solidified in place. The handles span vertically so that the athlete presses overhead with a neutral, or a hammer style grip.

The Log Clean and Press is a common event within strongman competitions. A log is more of a niche tool and has specific techniques associated with it. Logs are not typically used by athletes outside of the strongman sport, however there is merit to overhead pressing with a neutral grip as opposed to a pronated grip which is used with a typical barbell.

Sandbags

Sandbags consist of a heavy fabric sack filled with sand that may or may not have handles sewn-on. Sandbags are a dynamic way to train strength and power. They are frequently used by combat sports athletes such as MMA fighters and wrestlers.

Sandbags are also used by strength athletes such as strongmen and powerlifters as well as in obstacle course races. Common exercises with sandbags include throws, where the individual picks the sandbag off the ground and throws it over their shoulder, sandbag clean and presses, and sandbag squats.

Sandbag workouts are often structured around performing the repetitions of each exercise for a set amount of time or completing a certain number of repetitions using a submaximal weight but can also be done for maximum weight with careful attention to form.

When the weight is selected appropriately, sandbags are a fun and effective tool for improving the strength and conditioning of a healthy, adult population.

Suspension Trainers

Suspension trainers are adjustable-length straps suspended from the ceiling or high rack with handles or loops on the bottom that allow a variety of upper and lower body exercises to be performed. Suspension trainers effectively add instability to bodyweight movements when an individual places their feet or hands in the straps. Suspension trainers include gymnastic rings, TRX equipment, and other similar implements.

Suspension trainers also allow decreased intensity on a variety of bodyweight movements when gripping the handles with the hands. For example, they can be used for assisted squats in elderly populations who cannot safely perform standard bodyweight squats.

Common exercises on the suspension trainers include pushups, dips, knees-to-chest in a plank, planks, rear flies, and assisted squat variations.

Five Common Training Implements

Bodyweight

Using one's own bodyweight as resistance.

Exercise examples: pushups, pullups, jump squats.

Barbells

Straight metal bar of various specifications between 4 to 7 feet long, loaded with weight at both ends. The vast majority of traditional barbell exercises use a single bar.

Exercise examples: barbell bicep curl, back squat, power clean.

Dumbbells

Straight metal bar of various specifications between 6 to 12 inches long, loaded with weight at both ends and held in one hand. Dumbbell exercises often use two dumbbells, with one held in each hand, although many exercises can be performed with a single dumbbell.

Example exercises: dumbbell lateral raise, dumbbell overhead press, pec flies.

Machines

Pin or plate-loaded equipment that allows a fixed range of motion for a given muscle group.

Example exercises: machine chest press, leg press, lat pulldown.

Alternative Implements

Equipment such as kettlebells, sandbags, and strongman logs that allow for different, varied training stimuli for a variety of different fitness and performance goals.

Exercise examples: kettlebell swings, sandbag throws, log clean-and-press.

Summary

While there are nearly endless varieties of training systems, equipment and modalities available to fitness professionals, the vast majority of training programs for general fitness clients follow some variation of the resistance training protocols and equipment discussed in this chapter.

When using equipment, trainers must ensure clients follow proper form protocols and are familiar with the equipment they are utilizing.

Given the key role of fitness equipment in most training programs, trainers should spend substantial time using and familiarizing themselves with any and all equipment they use with clients.

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Chapter 16

Resistance Training Technique

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Introduction

Fitness professionals must have in-depth knowledge of proper exercise technique to ensure client safety when performing movements. Overall, proper technique in resistance training exercises provides the optimal training stimulus while reducing the risk of injury.

When introducing clients to exercises, observing proper form checkpoints at each phase of the movement is key to both giving proper verbal technique cues as well as identifying potential muscular imbalances.[1]

Key Injury Indicators

The most common areas injured during resistance training include the knees, shoulders, and back.[2] Therefore, common visual checkpoints for trainers to look for are proper knee tracking, shoulder complex alignment, and engagement, along with neutral spine positioning.

Knee valgus (knees caving in) is a risk factor for lower limb injury and a potential indicator of weakness in the hip abductor group.[3]

Research attributes scapular muscle strength discrepancy as a common cause of shoulder injury during resistance training. The typical shoulder muscle imbalances lead to elevation and internal rotation of the shoulder, which can occur at rest or during movements involving the glenohumeral joint. This pattern places unneeded pressure on the shoulder joint.[4] Therefore, trainers must keep a strong technical focus on scapular retraction and shoulder depression during pressing exercises.[5]

A neutral spine should be maintained through most resistance exercises, as it is the optimal position for power in sports-related movements and protects the muscular alongside the spine itself.[6] For those clients who have difficulty holding this position, fitness professionals should include proper core strengthening exercises which can aid them in the endeavor.[7]

Key Injury Prevention Checkpoints			
Checkpoint	**Observation**	**Risks**	**Cues**
Knees	Valgus (caving/rotated inwards)	Knee ligament injury	Activate knees outward
Shoulders	Elevation, internal rotation	Rotator cuff injury	Pinch shoulder blades back and downwards
Spine	Rounding or arching of lower back Rounding of upper back, forward head position	Lumbar, thoracic, or cervical spine injury Spinal muscle strains and sprains	Brace core and control breath Bring chin to chest slightly while tucking head backwards

The Three Rules of Weight Lifting

During resistance training, the following "rules of weight lifting" apply generally to most exercises. Note that for certain technique applications, deviation from these rules may be warranted, but for general resistance training, these rules should be followed.

1. Keep it close

When weight is further from the center midline of the body, the joints operate at an increasing mechanical disadvantage. This makes the same weight require more effort to lift and can place undue stress on stabilizer muscles that are not designed to exert against the typical resistance needed to train the prime mover muscles.

For example, during an overhead press, if the weight is too far in front of the body, the deltoids act with less leverage and the demands on the rotator cuff can quickly exceed safe capacity. In this instance, keeping the weight stacked vertically in-line with the spine throughout the full range of motion offers the safest and strongest movement path.

2. Move in a straight line

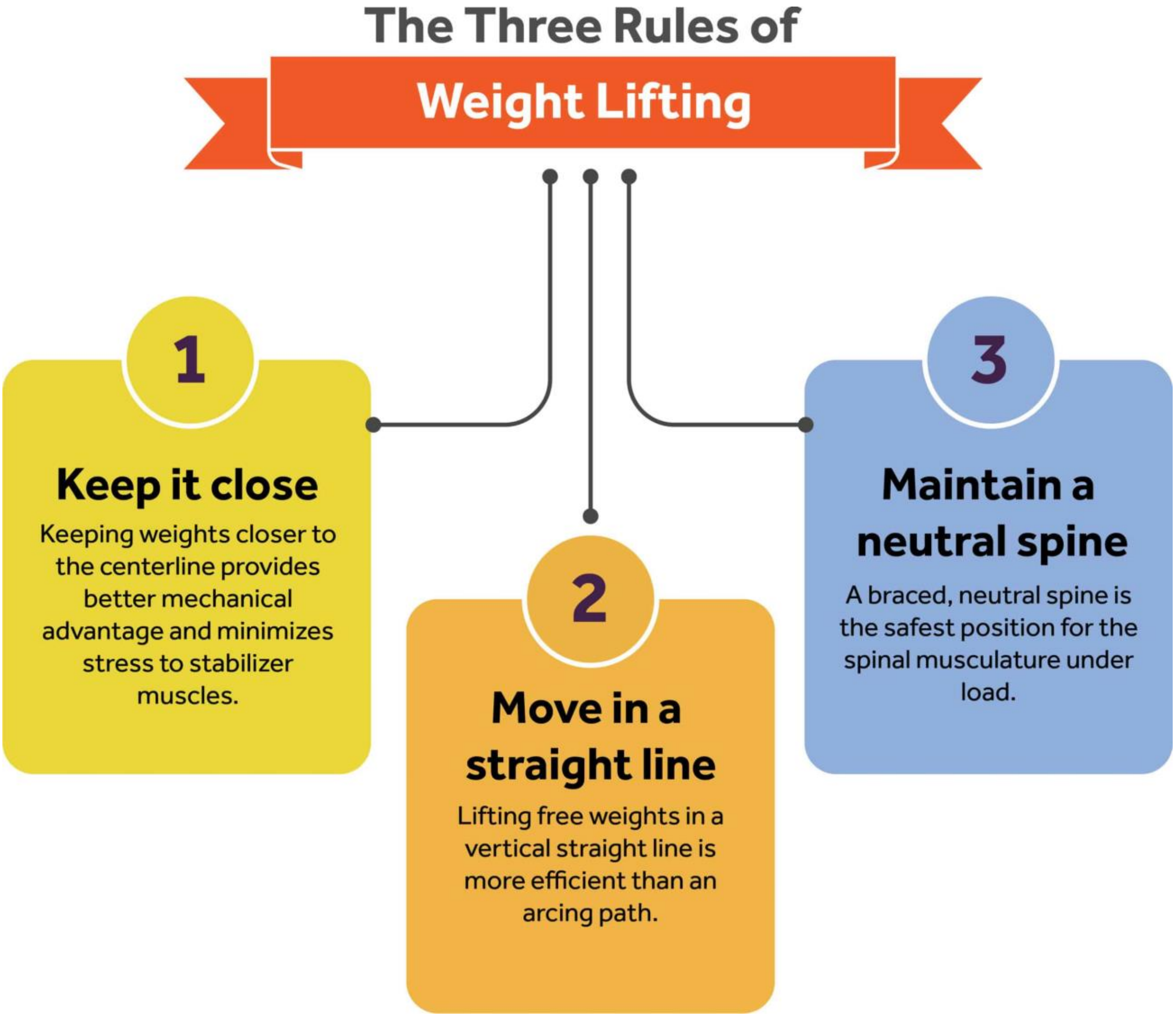
The closest distance between two points is a straight line. Any extra movement will make each rep more challenging as the lifter adds extra space they need to cover to complete the rep.

This is especially true on complex, multi joint exercises where lifters can fall into an "arc" pattern, which decreases the movement's efficiency and the mechanical advantage throughout the arc.

3. Maintain neutral spine

As mentioned above, neutral spine is the safest position for the musculature alongside the spine, which can be injured if placed under load and the vertebrae move out of position.

In sport-specific movements when the athlete needs to come out of neutral spine under load, they should still keep the core braced, which will reduce the potential for injury. Most general fitness clients should focus on the neutral spine brace when performing any heavy lifts.



Breathing During Resistance Training

Breathing is essential for not only correct exercise techniques, but for human life. The average lungs move around 17 fluid ounces of air with each normal breath, but during exercise that number shoots up to 101 ounces.

During a workout, levels of carbon dioxide and hydrogen ions increase in the bloodstream, causing a drop in pH and an increase in breathing rate. The primary trigger to breathe is actually to remove excess CO_2, not more oxygen.

Better breathing will increase exercise output during both cardiovascular and weight lifting endeavors.

During resistance training movements there are two breathing techniques to consider: when to breathe, and when to hold the breath.

When to Breathe

For most exercises, breathing in on the eccentric portion of the movement, and out on the concentric phase will provide the best pattern of breathing to follow.

In the case of a pull up, the lifter breathes out on the way up and in on the way down as they go through their repetitions.

For a back squat, they would start with a breath in on the way down and then release that breath on the way up before beginning again.

When Not to Breathe

Sometimes, especially on heavy low repetition sets, it's helpful to take one deep breath and hold it while bracing the core and pushing air against a closed glottis throughout the working set. This is called "the Valsalva maneuver," and is very effective at creating intense pressure throughout the body that provides spinal stability, allowing the body to support substantial weight.

Note that this can be a dangerous technique to implement, especially for any set greater than a few repetitions, because without oxygen, humans can pass out and potentially even suffer greater negative consequences.

For this reason, the Valsalva maneuver is best used with intermediate and advanced clients training for maximal strength.

Technique for Selected Resistance Exercises

Bodyweight Movements

Push Ups

Safety Checkpoints:

- Keep core braced and maintain neutral spine during movement.
- Shoulders should be pulled back and down to protect joints.
- Make sure to stack wrists under elbows.
- Hand placement will vary based on personal preference.
- Allowing the elbows to flare more increases chest activation, but puts the shoulder in a more compromised position so consider focusing on pushing elbows back rather than out in the movement.
- If the flattened hand position hurts the wrists, consider using push up stands (or two dumbbells) to keep wrists straight or limit the ROM of the exercise if needed to 90 degrees.

Exercise Instructions:

1. Start in the plank position, creating a straight line from head to heel. Hands should be directly outside shoulders with elbows extended, fingers facing slightly outwards.
2. Engage the core and lower the body, by allowing the elbows to flex until the chest lightly touches the ground, then come back up.

Coaching Tips:

- Observe client's elbows to ensure they point back at a 45-degree angle while maintaining vertical stack above the wrist during the movement.
- If they are unable to perform a traditional push up, regress the exercise to either push ups with the hands on an elevated box or push ups on the knees.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Pull Ups

Safety Checkpoints:

- Keep active shoulders during movement. Scapula should be pulled back and down.
- Watch for scapular winging during retraction.
- Watch for shoulders shrugging during pull up as it can place excessive pressure on the joint.
- Keep core engaged.
- Control the eccentric portion of the movement and limit excess hip or lower back involvement; often people use a lot of extra body motion to reach their chin or clavicle above the bar, which increases potential for injury and limits use of the muscles this movement seeks to target.

Exercise Instructions:

1. Start directly under a bar set at a height from which you can hold on to with the elbows fully extended, without feet touching the floor.
2. Place hands slightly outside shoulders with palms facing forward and feet off the ground.
3. Pull the shoulder blades back and down to initiate movement and bring the body up, bending the elbows, until the chin (or chest) touches or raises over the bar.
4. Complete the repetition by lowering down to the starting position with the elbows fully locked out.

Coaching Tips:

- Alternative grips exist at underhand and neutral, changing the associated muscular recruitment and overall difficulty of the pull up as well as differences in the width distance of the grip.
- If a client is unable to perform a standard pull up or chin up, utilize either a pull up machine or pull up bands to reduce the weight needed to overload the muscles properly.

Targeted Major Muscle Groups:

- latissimus dorsi
- trapezius
- rhomboid

Dips

Safety Checkpoints:

- Neutral head posture throughout the range of motion.
- Elbows stacked above wrists to avoid excessive wrist flexion.
- Maximize ROM while considering mobility restrictions, not everyone will be able to safely lower all the way.

Exercise Instructions:

1. Start with hands planted on parallel bars.
2. Step or jump into position so that arms are supporting the weight of your body while elbows are fully extended.
3. Lower body until shoulders are below height of elbows.
4. Return to full extension to finish the rep. Knees can remain flexed throughout the movement if need be.

Coaching Tips:

- A more upright posture with elbows pointed back will emphasize triceps, while a greater lean forward with elbows flared will emphasize chest (although be careful with flaring the elbows too much as this can put excess pressure on joints).
- If unable to perform a dip, clients can use a bench or box instead of a parallel bar: Have them plant hands slightly outside shoulder width with fingers facing forward on the implement. Elbows begin fully extended with legs straight, resting on heels. Lower body towards the floor until shoulders are below the height of elbows. Return to full elbow extension to finish the rep.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Air Squats

Safety Checkpoints:

- Knees fall in line with the path of toes specifically, second metatarsals.
- Maintain neutral spine and upright posture.
- Make sure knees do not buckle inwards during motion.

Exercise Instructions:

1. Stand with feet outside hip width, toes pointed forward or slight out.
2. Push the hips back and down, keeping the chest open (as if sitting down into a chair) until the hips drop below the knees.
3. Stand back up.

Coaching Tips:

- As the client lowers into the squat, their weight should be positioned toward the midfeet, right below the ankle.
- Some people may prefer putting their arms out in front during movement to help with balance.
- If the client cannot perform a full squat safely, because of injury or balance or coordination issues, have them start by squatting onto a box or bench, practicing the correct form. Over time the trainer can lower the height of the implement until the client can squat safely without any assistance.

Targeted Major Muscle Groups:

- gluteal muscles
- quadriceps femoris

Lunges

Safety Checkpoints:

- Knees fall in line with the path of toes specifically, second metatarsals.
- Maintain neutral spine and upright posture.
- Make sure knees do not buckle inwards.
- Do not put excess pressure onto the back leg.

Exercise Instructions:

1. Stand with feet hip distance apart.
2. Step forward a few feet with one leg and lower the hips, allowing the front knee to bend until the back knee lightly touches the floor,
3. Rise back up and bring the front forward foot back to the starting position. Finish repetitions on one side and repeat for the other leg.

Coaching Tips:

- If the client cannot lower into the lunge, have them instead step up onto a box. This movement is the same as the lunge but in reverse as it begins with the concentric phase of the movement instead of the eccentric.

Targeted Major Muscle Groups:

- gluteal muscles
- quadriceps femoris

Dumbbell Movements

Bent Over Row

Safety Checkpoints:

- Maintain neutral spine.
- Shoulder blades should be pulled back and down as weight comes up.

Exercise Instructions:

1. Start standing, holding two dumbbells at sides.
2. Push hips back and lower torso while keeping back flat until dumbbells are at knee height.
3. Pull dumbbells to the torso allowing elbows to flex at a 45-degree angle. Dumbbells will stop next to either side of the ribcage.
4. Slowly lower back to full extension while keeping the torso stationary.

Coaching Tips:

- This exercise can also be done one arm at a time with the hand and knee of the opposite side supported on a bench, which reduces lower back load.
- If the dumbbells are pulled higher on the body, like to the chest line, it activates the rhomboids more. If the dumbbells are pulled lower to the ribcage, that involves more of the lats.

Targeted Major Muscle Groups:

- latissimus dorsi
- trapezius
- rhomboids
- posterior deltoid

Flat Chest Press

Safety Checkpoints:

- Maintain head, shoulders and tailbone contact with bench or flat surface.
- Vertical forearms and wrists.
- Shoulder blades pull back and down.
- Keep core braced and torso tight, maintaining a stable base.

Exercise Instructions:

1. Lie on a flat bench holding two dumbbells.
2. You can use knees and arms to push the weights up into the starting position over the chest or have someone help position them there.
3. Lower the weights to the chest. Elbows can open up to 45-degrees of the torso.
4. Once the weights lightly touch the chest, push them back up, extending the elbows.

Coaching Tips:

- For extra power, have the client keep contact with the floor during the entire movement and push through the legs and feet, while keeping hips on bench to drive the dumbbells up.
- Different elbow angles will work for different people, but a wider elbow has the potential to aggravate the elbow and shoulder joints.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Incline Chest Press

Safety Checkpoints:

- Maintain head, shoulders and tailbone contact with bench or flat surface.
- Vertical forearms and wrists.
- Shoulder blades pull back and down.
- Keep core braced and torso tight, maintaining a stable base.

Exercise Instructions:

1. Lie on an incline bench holding two dumbbells.
2. You can use knees and arms to push the weights up into the starting position over the chest or have someone help position them there.
3. Lower the weights to the chest. Elbows can open up to 45-degrees of the torso.
4. Once the weights lightly touch the chest, push them back up, extending the elbows.

Coaching Tips:

- Bench angle varies from an incline of 15-60 degrees for this exercise. The angle will change depending on goals and preferences, but for most, a lower degree angle in the 15-30 degree will suit goals best as it places more emphasis on the pectoralis muscle and less strain on the shoulders.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Overhead Press

Safety Checkpoints:

- Upright torso with neutral spine.
- Push the weights straight overhead, perpendicular to the floor.
- Keep abs braced.
- Make sure mobility is adequate before excessively loading this movement.

Exercise Instructions:

1. Dumbbells held at shoulder height.
2. Brace core and press the weights straight over head to full elbow extension, directly over each respective shoulder.
3. Lower the weights with control.

Coaching Tips:

- Having clients keep elbows tucked in will increase triceps involvement and help maintain external rotation, while letting elbows open outwards allows more shoulder and chest involvement but increases the likelihood of impingement.
- This exercise can be performed seated or standing.

Targeted Major Muscle Groups:

- anterior deltoid
- medial deltoid
- triceps brachii

Bulgarian Split Squat

Safety Checkpoints:

- Keep torso upright and midline stable.
- Forward knee stays in line with second metatarsal during flexion and extension.
- Make sure knee does not buckle inwards.

Exercise Instructions:

1. Hold a pair of weights, arms hanging on either side of the torso.
2. Targeted leg will have the foot planted on the floor with the opposite leg elevated and its foot resting on a bench/block/box at knee height behind the lifter. Planted foot should be in front of the torso rather than vertically stacked.
3. Begin the movement by lowering the torso to the floor allowing the planted leg to bend. Avoid the planted knee going past the toes by driving the elevated knee towards the floor.
4. Return to single leg standing to complete the repetition.

Coaching Tips:

- This movement is often done holding two dumbbells at the sides, but can also be done with one dumbbell held in a front rack position or with a barbell racked on the client's shoulders.
- The length of the step of the forward leg from the back leg will change the muscle emphasis: a shorter step recruits more quad musculature and a longer step will focus more on glute muscles.

Targeted Major Muscle Groups:

- gluteal muscles
- quadriceps femoris

Goblet Squat

Safety Checkpoints:

- Upright torso with neutral spine.
- Elbows stack under wrists and tuck tight into the mid section.
- Knees stay in line with second metatarsal.

Exercise Instructions:

1. Stand with feet outside shoulder width, holding a dumbbell with both hands at sternum. Toes pointed forwards or slightly outwards provided knees track with toes.
2. Push hips back and sit tailbone as low as possible (ideally lower than the height of the knees) while maintaining an upright torso.
3. Return to standing to complete the repetition.

Coaching Tips:

- This is a great movement to teach clients who lean forward too much when they squat, because the weight is placed on top of the chest and any leaning forward will dramatically increase the difficulty of the movement.
- While this movement provides many benefits, as clients progress it becomes harder and harder to load it properly enough to tax the legs, because the weight must be held in place using the shoulders and arms, which are not as strong.

Targeted Major Muscle Groups:

- quadriceps femoris
- gluteal muscles

Lateral Raise

Safety Checkpoints:

- Torso upright and static during movement.
- Minimal elbow flexion during ROM.

Exercise Instructions:

1. Start standing or seated, holding a pair of weights by the hips.
2. Perform the lateral raise by raising both arms to shoulder height directly to the side of each respective shoulder. Body should present a "t" at the top of the movement with arms parallel to the floor and each other.
3. Return arms to the sides of the hips to complete the repetition.

Coaching Tips:

- Have clients use a minimal bend at the elbows during exercise.
- This movement is best done for higher repetitions with lighter weights.

Targeted Major Muscle Groups

- medial deltoid

Dumbbell Snatch

Safety Checkpoints

- Maintain neutral spine.
- Hips are the driving force behind this movement, not arms.
- Weight travels in a straight path.
- Clients need excellent mobility to load this movement.
- This movement requires much more coaching than most other exercises.

Exercise Instructions

1. The goal of this movement is to attempt to lift the dumbbell placed in front of you in one smooth motion from the ground to overhead. This is accomplished through three phases of movement: the jump, the transition, and the catch.
2. The jump: squat down to reach the weight with a straight arm. Bring the weight to shin height, then explode with their lower body using triple extension (extension of the hips, knees, and ankles) to drive the weight into the air.
3. The transition: as the dumbbell travels through the air, bend your elbow, allowing the weight to be flipped from the wrist pointing down to the wrist facing up.
4. The catch: immediately after the weight is flipped up, stabilize the weight over your center of gravity with a straight arm. You can do this by dropping into either a full squat (in the full snatch) or a quarter squat (in the power snatch).
5. When momentum stops, the weight should be locked out overhead and the body should be in a squat or dip.
6. Finish the move by standing completely upright with the weight overhead.
7. After this the weight is returned back to the ground.

Coaching Tips

- As clients bring the weight down, have them bring their hips back to take the force of the movement, instead of the spine.
- Teach this movement in stages, using the three phases separately before integrating them together in the whole movement.
- A snatch is the fastest way to move a dumbbell from the ground to straight overhead.

Targeted Major Muscle Groups

- Total body power movement

Bicep Curls (supine grip)

Safety Checkpoints:

- Upright stable torso.
- Shoulders retracted and depressed.
- Avoid excessive body movement.

Exercise Instructions:

1. Hold weights with a supinated grip (palms out) with straight arms by sides. Weights should be just in front of the hips.
2. Keeping shoulders retracted and depressed, flex the elbows to bring weights to shoulder height while minimizing any accessory movement through the body.
3. At the top of the movement, palms should be facing shoulders. Upper arm should remain in contact with torso.
4. Slowly lower back to the start position to complete the repetition.

Coaching Tips:

- Can be performed standing or seated.
- To help clients do this movement correctly without any extra body motion, you can teach it while having clients lean against a wall, making sure to keep their back against the wall during the movement.

Targeted Major Muscle Groups:

- Biceps brachii

Biceps Curl (hammer/neutral grip)

Safety Checkpoints:

- Upright stable torso.
- Shoulders retracted and depressed.
- Avoid excessive body movement.

Exercise Instructions:

1. Hold weights with a neutral grip (palms facing hips) and straight arms. Weights should be by the side of the hips.
2. Keeping shoulders retracted and depressed, flex the elbows to bring weights to shoulder height while minimizing any accessory movement through the body.
3. Upper arm should remain in contact with torso and palms should face each other throughout the repetition.
4. Slowly lower back to the start position to complete the repetition.

Coaching Tips:

- Can be performed standing or seated.

Targeted Major Muscle Groups:

- biceps brachii
- brachioradialis

Chest Fly

Safety Checkpoints:

- Torso stays in contact with bench during movement.
- Slight flex at elbows.
- Weights should start stacked directly above shoulder and at maximal abduction should present a symmetrical line from right to left wrist.

Exercise Instructions:

1. Lie flat on a bench with a pair of weights extended directly above the chest. Maintain a slight amount of elbow flexion.
2. Slowly abduct the weights to the sides maintaining arm length to spread the chest while also retracting shoulders. Upper body should be nearly parallel from weight to weight at the bottom of the movement.
3. Adduct the weights back together over the chest to complete the repetition.

Coaching Tips:

- Have clients arch their back slightly on the bench to help open up the chest, along with retracting their shoulders.
- There is much more tension at the bottom of the movement than the top, so focus on that range of motion more for hypertrophy work.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Barbell Movements

Bench Press

Safety Checkpoints

- Maintain head, shoulders and tailbone contact with bench or flat surface.
- Vertical forearms and wrists.
- Shoulder blades pull back and down.
- Keep core braced and torso tight, maintaining a stable base.
- Bar should follow a symmetrical range of motion for both right and left sides.
- When using heavy weights, this movement requires a spotter or stable safety pins.

Exercise Instructions:

1. Lie on a bench with barbell racked, hands gripping barbell outside shoulder width.
2. Unrack the barbell and bring it over the height of the chest.
3. Pin the shoulder blades back against the bench and lower the weights to the chest. Elbows can open up to 45-degrees of the torso.
4. Once the bar lightly touches the chest, push it back up, extending the elbows completely.

Coaching Tips:

- For extra power, have clients keep contact with the floor during the entire movement and push through the legs and feet, while keeping hips on the bench to drive the barbell up.
- A back arch will aid in total body stability and strength during movement, but it makes the press more of a full body move and can shorten range of motion.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii
- anterior deltoid

Overhead Press

Safety Checkpoints:

- Upright torso with neutral spine.
- Push the weight straight overhead, perpendicular to the floor.
- Keep abs braced.
- Make sure mobility is adequate before excessively loading this movement.
- Make sure client moves their head out of the way of the bar path.

Exercise Instructions:

1. Start with the barbell held at shoulder height with palms facing forward and elbows to the side of the torso. Grip should be spaced just outside shoulder width.
2. Brace core and press the weights over head to full elbow extension, making sure to move head out of the way of the bar’s straight path. Keep active shoulders at the top of the movement.
3. Lower the weight with control.

Coaching Tips:

- Can be performed seated or standing.
- Having clients tuck elbows in will increase triceps involvement and help maintain external rotation, while letting the elbows open outwards allows more shoulder and chest involvement, but increases the likelihood of impingement.

Targeted Major Muscle Groups:

- anterior deltoid
- medial deltoid
- triceps brachii

Incline press

Safety Checkpoints:

- Maintain head, shoulders and tailbone contact with bench or flat surface.
- Vertical forearms and wrists.
- Shoulder blades pull back and down.
- Keep core braced and torso tight, maintaining a stable base.
- Bar should follow a symmetrical range of motion for both right and left sides.
- When using heavy weights, this movement requires a spotter or stable safety pins.

Exercise Instructions:

1. Lie on an incline bench with barbell racked, hands gripping barbell outside shoulder width.
2. Unrack the barbell and bring it over the height of the chest.
3. Pin the shoulder blades back against the bench and lower the weights to the chest. Elbows can open up to 45-degrees of the torso.
4. Once the bar lightly touches the chest, push it back up, extending the elbows completely.

Coaching Tips:

- For extra power, have clients keep contact with the floor during the entire movement and push through the legs and feet, while keeping hips on the bench to drive the barbell up.

Targeted Major Muscle Groups:

- pectoralis major/minor
- triceps brachii, anterior deltoid

Back Squat

Safety Checkpoints:

- Knees fall in line with the path of toes specifically, second metatarsals.
- Maintain neutral spine and upright posture.
- Make sure knees do not buckle inwards during motion.
- For heavy weights use safety pins in case lifter gets stuck at the bottom.

Exercise Instructions:

1. Start with the barbell resting on a squat rack at shoulder height.
2. Bring your body under the barbell, letting the bar rest on the shoulders behind the head. Barbell should be resting on the upper trapezius across the back without putting any pressure on the neck's vertebrae. Hands go just outside the shoulders on the bar.
3. Extend the knees to lift the barbell from the rack and step into free space for the exercise.
4. Begin the movement by pushing hips back and down to lower body towards the floor allowing knees to bend. Ideally knees track in line with toes while torso remains upright.
5. Control the lowering of the body then when max depth is reached (lower than parallel) drive the weight back up to a standing position by extending throughout the hips and legs.

Coaching Tips:

- Use the greatest ROM possible with this exercise and then standardize the depth, otherwise progression will be harder to control.

Targeted Major Muscle Groups:

- gluteal muscles
- quadriceps femoris

Deadlift (Standard)

Safety Checkpoints:

- Vertical bar path.
- Keep the weight close to body.
- Shoulders remain retracted during movement.
- Hip drive is catalyst for movement, not lower back extension.

Exercise Instructions:

1. Bar starts on the floor in front of you.
2. Push your hips back and down and roll the bar in until it’s as close as possible to the shins.
3. Grabbing the bar right outside their knees, extend your hips and stand up with the bar.
4. Return the barbell in the same path to the floor to complete the repetition.

Coaching Tips:

- The goal of the movement is to lift the bar from the floor in as vertical a line as possible by driving hips forward to a standing position.
- Emphasize a full standing posture without hyper-extension of the low back (which may require ab and glute activation).
- Grip options are either double overhand, mixed (under and over), or double overhand with a hook grip. If you clients prefer to use a mixed grip, make sure to alternate which hand is over and under to avoid muscle imbalances.

Targeted Major Muscle Groups:

- gluteal muscles
- hamstrings, quadriceps femoris, latissimus dorsi

Deadlift (Romanian)

Safety Checkpoints:

- Vertical bar path.
- Keep the weight close to body.
- Shoulders remain retracted during movement.
- Hip drive is catalyst for movement, not lower back extension.
- Knees angle stays constant.

Exercise Instructions:

1. Starts standing up with the bar held at mid thigh level with minimal knee bend.
2. Push your hips back allowing the bar to travel downwards as far as possible without bending the knees any more.
3. Once the hips are as far back as possible, loading the hamstrings, contract your glutes and bring the weight back up.

Coaching Tips:

- Some people will be able to keep the legs completely straight during movement and some will need a slight bend so vary based on mobility of the client.
- Tell clients to think about, “sitting back” during the movement to emphasize the hip motion more.

Targeted Major Muscle Groups:

- gluteal muscles hamstrings

Power Clean

Safety Checkpoints:

- Maintain neutral spine.
- Hips are the driving force behind this movement, not arms.
- Weight travels in a straight path.
- Need to be able to split exercise into 3 phases: pull, dip/transition, catch.
- This movement requires much more coaching than most other exercises.

Exercise Instructions:

1. Lift the weight in one smooth motion from the ground to your shoulders. This is accomplished through three phases of movement: the jump, the dip, and the catch.
2. The jump: squat down to reach the weight with straight arms, grabbing just outside hips. Bring the weight to shin height, then explode through the lower body using triple extension (extension of the hips, knees, and ankles) to drive the weight into the air.
3. The transition/the dip: as the barbell travels through the air, bend your elbows, allowing the weight to be flipped from the wrist pointing down to the wrist facing up. While this is happening, dive underneath the bar.
4. The catch: immediately after the weight is flipped up, you need to stabilize the weight. Do this by dropping into either a full squat (in the full clean) or a quarter squat (in the power clean) under the bar, pulling your elbows up and in so you can catch it.
5. When momentum stops, the weight should be held in a front rack position and the body should be in a squat or dip.
6. Finish the move by standing completely upright with the weight on the shoulders.

Coaching Tips

- When the client brings the weight back to the ground, coach them to bring their hips back to take the force of the movement as the barbell drops off of the shoulders.
- Teach this movement in stages, using the three phases separately before integrating them together in the whole movement.
- A clean is the fastest way to move a dumbbell from the group to the shoulders.

Targeted Major Muscle Groups

- Total body power movement

Bent Over Row

Safety Checkpoints

- Maintain neutral spine.
- Shoulder blades should be pulled back and down as weight comes up.
- Arms remain symmetrical throughout the movement.

Exercise Instructions

1. Start standing, holding the barbell with extended hanging arms directly in front of the hips.
2. Push hips posteriorly while keeping back flat until the barbell is just below knee height.
3. Pull barbell to torso with the weight meeting torso at approximately the bottom of the sternum, allowing elbows to flex out at a 45-degree angle.
4. Slowly lower back to full arm extension to finish the repetition.

Coaching Tips

- Variations of this exercise include the t-bar row, Yates row, and Pendley row. Different variations will work for different clients as well as different grip positions.
- It's very easy for the hips to aid in the movement, so choose the load, repetitions, and volume that allows proper technique for clientele.

Targeted Major Muscle Groups

- latissimus dorsi
- trapezius
- rhomboids
- posterior deltoid

Biceps Curl

Safety Checkpoints

- Shoulders should remain depressed and retracted throughout the movement.
- Torso remains upright.
- Avoid swaying during exercise.

Exercise Instructions

1. Stand, holding the barbell with a supinated grip (palms out) and straight arms at shoulder width apart. Barbell should be just in front of the hips.
2. Keeping shoulders retracted and depressed, flex the elbows to bring barbell to shoulder height while minimizing any accessory movement through the body. At the top of the movement, palms should be facing shoulders. Upper arm should remain in contact with the torso.
3. Slowly lower back to the start position to complete the repetition.

Coaching Tips

- To help clients do this movement correctly without any extra body motion, you can teach it while having clients lean against a wall, making sure to keep their back against the wall during the movement.
- Variations of the barbell curl include preacher curls, spider curls, partial repetitions, and curls utilizing an E-Z bar for more range of motion and better wrist position.

Targeted Major Muscle Groups

- Biceps brachii

Machine Movements

Lat Pulldown

Safety Checkpoints

- Keep active shoulders during movement. Scapula should be pulled back and down.
- Watch for scapular winging during retraction.
- If elbows flare out to the side during pulldown, it places extra pressure on the shoulders so watch for this.

Exercise Instructions

1. Set the thigh pad pin so that your knees fit snugly into the opening and the correct weight.
2. Reach or stand up and grab the bar, using your body weight to bring it overhead with straight elbows as you get into position.
3. Pull the shoulder blades back and down to initiate movement and bring the bar down, bending the elbows, until the chin (or chest) touches or raises over the bar.
4. Complete the repetition by allowing the bar and cable to return to the starting position with the elbows fully locked out.

Coaching Tips

- Experiment with different grip widths, but for most clients, directly outside the shoulders will be best with a pronated or supinated wrist position.
- As the weight travels back up, make sure clients aren't being pulled out of the seat.

Targeted Major Muscle Groups

- latissimus dorsi
- trapezius
- rhomboid

Calf Raise

Safety Checkpoints

- Use full range of motion and control descent.

Exercise Instructions

1. Select the appropriate height on the machine so you can stand or sit and still complete the entire movement without obstruction.
2. If standing, place the pads on your shoulders, if seated they go above your knees.
3. Push the weight through your ankles and feet and come up as far as you can onto the toes.
4. Lower all the way down and repeat.

Coaching Tips

- Calf raises are best used with high repetitions and lower rest times.
- Have your clients use the most ROM as possible, getting a stretch at the bottom as well as the top of movement.
- Clients can point their toes forward, in, or out, which may recruit different sides of the calf, although the best foot position is going to be whichever allows the client to do the most quality repetitions.

Targeted Major Muscle Groups

- gastrocnemius
- soleus

Leg Curl

Safety Checkpoints

- Make sure machine angles are lined up with joints.
- Control eccentric.

Exercise Instructions

1. Set up the machine so pads lie flat against the lower back. Raise your legs and slip them into the padded lever. The leg pad should sit on the lower calf. Drop the lap pad so that it sits comfortably tight above the knees.
2. Start each repetition by pulling your legs back toward your glutes as far as possible.
3. Hold for a one second at the finish point and return the weight back to the start.

Coaching Tips

- Most machines will have dots or markings to indicate where the knee joint should line up with the machine, so double check the machine.
- There are several types of leg curl machines including lying and seated. Both will work well.

Targeted Major Muscle Groups

- hamstrings
- gluteal muscles

Leg Press

Safety Checkpoints

- Knees fall in line with the path of toes specifically, second metatarsals during motion.
- Make sure knees do not buckle inwards during motion.

Exercise Instructions

1. Load the machine with the weight and sit down.
2. Position your feet on the sled slightly outside hip width.
3. Extend your knees and unlock the safety devices.
4. Lower the weight under control as far as possible with the knees tracking over the feet and the lower back flat against the seat.
5. Pause briefly and then drive the weight back to the initial position by extending the knees. Do not lock out the knees completely but maintain a slight flex at the top of the movement.
6. Complete the repetitions and then relock the safeties.

Coaching Tips

- The range of motion will be dictated by client's mobility, but seek to lower the weight past a 45 degree knee angle.
- Placing feet higher on the sled or lower will be different based on goals and anthropomorphics of clients, but the main goal should be to put the knee in a safe position.

Targeted Major Muscle Groups

- Gluteal muscles, quadriceps femoris

Triceps Pushdown

Safety Checkpoints

- Maintain neutral spine, use triceps to control movement, not lower back.

Exercise Instructions

1. Pick either a rope or a v-shaped bar attachment and clip it into the cable system.
2. Raise the height of the rope to eye level using the drop pins.
3. Stand upright leaning very slightly forward with your upper arms close to the body.
4. Grab tightly with both hands on either side of the device, and bring the rope down until the elbows are fully extended, perpendicular to the floor.
5. Hold for a second and return the rope up to the starting position.

Coaching Tips

- As the client brings the rope or bar down, allow their elbows to open out slightly, which will help with the muscle contraction.

Targeted Major Muscle Groups

- Triceps brachii

Summary

Proper exercise technique prevents risk of injury and targets the correct muscles used in the movement. Additionally, coaching the correct motion pattern requires knowledge, communication skills, and patience.

Above all, fitness professionals must make sure their clients can perform exercises properly before adding extra resistance, because as weights increase it becomes very easy for minor changes in movement to create large impacts on the body in both a positive and negative way.

Generally, stressing the three rules of weightlifting and correct breathing will go a long way, but each exercise contains specific cues that enhance the movement and aspects to watch out so correct technique on that exercise is essential.

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Chapter 17

Program Design

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Introduction

Understanding how to design an effective program seems an easy task; however, it can be an intensive process. Training programs guide an individual through their training in an organized fashion in order to achieve optimal results.

Anyone can take several exercises and perform them in succession, but it is job of the fitness professional to use knowledge and common sense to pick the right set of exercises and perform them in the correct order to both maximize improvements in fitness and minimize risk of injury for the client.

Programs must consider a myriad of variables that may change the design fundamentally. Some variables involve the actual workouts while others involve the client's strengths, limitations and goals. An endurance program will look vastly different compared to a strength program. An older client's program will be in stark contrast to a younger client's program.

This chapter will cover different program variables and their uses as well as giving fitness professionals a way to organize training schedules to best fit the needs of a client.

Program Design Variables

A training program requires manipulation of multiple variables to be effective. Each variable carries important factors with it. Each variable's manipulation may alter how a program affects a client's progression. The following will explain important training variables that will be a part of every training program.

Sets

A set is a grouping of several repetitions of an exercise or a number of reps performed without rest.[1] Most workout programs include several sets per exercise. However, some may only use one set per exercise for beginners or one extended set. Exercises will typically have 1-3 warm up sets followed by 3-5 working sets.

A warm up set uses lighter weights to prepare the body for the working sets, while a working set is the set using the assigned intensity, reps, and tempo. Usually a rest break is required between sets, which can vary from a few seconds up to ten minutes depending on the goals of the workout.

Reps

A repetition, or rep, is one instance of an exercise. One set will have 1-30 reps typically. Different rep ranges are related to the type of stimulus they typically provide a muscle or muscle group. Each rep range is related to either hypertrophy, strength, power, muscular endurance, or a multiple other training goals discussed later.

Generally, most reps involve moving the weight to its required destination and then back, although in some instances reps involve no movement or partial range of motion.

Intensity

The intensity of an exercise typically refers to its percent of a 1 repetition max (%1RM). Intensity levels correspond to different goals. For example, 90% 1RM or higher is typically related to power, maximal strength, and for some athletes, a peaking phase.

Different intensity ranges will be discussed later in this chapter. Intensity can also refer to how challenging a rep or set feels to the individual based on the rate of perceived exertion (RPE).

Tempo

Repetition Tempo, or rep tempo, is the speed at which a rep is performed during a given set. Rep tempo is often displayed as 3 to 4 digits, such as 2-1-2 or 2-1-2-0. 2-1-2 denotes a 2 second eccentric phase, 1 second pause at the bottom of the rep, and 2 second concentric phase. The fourth number would represent the time between finishing one rep and starting the next.

A slower rep tempo has been shown to be more effective than a typical one when it comes to hypertrophy, but the difference is insignificant when a set is pushed to a similar proximity to failure.

Volume

Training volume is an accumulation of how much work a trainee performs in a given workout or program. To find training volume, multiply sets, reps, and the weight used. For example, a lifter performs 4 sets of 15 reps at 225lb on the back squat. Their training volume will be 13,500lbs of training. It is important to note that 15 sets of 4 reps at 225lb may equal 13,500lbs of training volume, but it is not the same stimulus, because of the rep range and relative intensity.

Training volume is also considered on a weekly basis. The total amount of sets performed on a body part is crucial for hypertrophic progression.

Currently the MV, MEV, MAV, and MRV systems are a common measure for weekly training volume. MV, or maintenance volume, is the number of weekly sets to maintain current amounts of muscle. MEV, or minimum effective volume, is the minimum weekly number of sets for a muscle or muscle group to grow. MAV, maximal adaptive volume is the optimal number of sets performed in a week for a muscle or body part to grow. Finally, MRV, or maximum recoverable volume is the maximal number of sets that a client can perform and still recover for that body part's next training session.

Rest

A rest interval describes time between sets that is dedicated to acute recovery, or the ability to recover enough to perform the next set. The rest interval typically lands in between 30 seconds and 180 seconds. Shorter rest periods (30-60 seconds) are linked with greater hypertrophic responses while longer rest periods (3-5 minutes) are linked with greater maximal strength responses.[2]

What is more important, is that the trainee takes enough time to fully recover before the next set without taking so long that they are not prepared for the next set. Some rest periods go as long as ten minutes or more if needed.

Frequency

Training frequency defines how many times someone trains a body part per week. Beginners usually start with once a week and high level athletes may train 6-8 times a week, including days where they train twice in that one day. Training frequency typically requires an inverse relationship with training duration in order to accumulate enough training volume per week for growth.

Duration

Training duration describes how long a training session lasts. Typically, a training session lasts 30 minutes up to 2 hours depending on workout structure, rest intervals, training volume, and, of course, time wasted. In some cases, training sessions can be shorter than 30 minutes or longer than 2 hours, but this is beyond the scope of this text.

Exercise Selection

The exercises a trainer or coach picks change according to goals, time, and equipment available. A bodybuilder uses certain exercises that differ from a powerlifter. A lifter with a knee injury will pick different exercises than a lifter with no injuries. A gymnast will perform different exercises than a football player, and so on. Poor exercise selection can also increase the risk of injury.

Heavy movements paired with explosive movements afterwards can be detrimental for some lifters, or high rep exercises followed by sprints. Proper exercise selection can maximize the utility of a training session and should be sports specific.

Selecting Variables for Common Fitness Goals

A coach or trainer must design a program that focuses on achieving the client's personal or sports-related goals. There are five common overall training goals: stability, muscular endurance, hypertrophy, strength, and power. While several of them have overlap, training for each can be quite different.

Stability

Stability training refers to training with the intention of improving balance and neuromuscular control, normally handled by type I muscle fibers.

This kind of training goal commonly includes beginners or people recovering from injuries.

Reps can be moderate or high (15-20) depending on the experience of the client, or reps can be time based. Loads are typically very low in this category while reps are high or time based.

Coaches often program low training volume because of the nature of this kind of training. Exercises include use of unstable surfaces or unilateral, or single sided movements.

New trainees need to build up their stability for heavier lifts later in the training career, so while this is an individual training goal for many, it is also a stepping stone.

Muscular Endurance

Muscular endurance refers to the ability for a muscle to produce force for extended periods of time. Muscular endurance training focuses on type I muscle fibers. This occurs through long training sessions that seek to emulate the requirements of endurance events, or for occupations that require endurance on a day-to-day basis.

There are no specific exercises more conducive to muscular endurance training. Muscular endurance training usually requires low intensity loading with a high number of reps, such as 15 or more at below 60% 1RM.[3]

In some cases, workouts include a higher amount of working sets, but usually, muscular endurance training will keep working sets on the lower end, usually around three sets per exercise.

Hypertrophy

Hypertrophy refers to the growth of muscle. Hypertrophy training benefits most training goals, but many trainees are primarily concerned with just increasing muscle mass.

Hypertrophy training involves all muscle fibers, but type II fibers are larger and more conducive to hypertrophy. Clients seeking this goal range from the typical gym goer who wants to look better to an aspiring bodybuilder or powerlifter preparing for their next strength phase.

Most resistance training movements are effective for hypertrophy, but many bodybuilders will opt for machines when applicable to remove some unnecessary fatigue from the stabilization of free weights.

Hypertrophy can be elicited with sets of 5-30 reps, but more often trainees use sets of 6-12 reps with medium to high loads and low to moderate rest intervals at or greater than 30% 1RM.[4,5]

A 1-3 second concentric phase and a 2-4 second eccentric phase is cited to be the optimal rep tempo for muscle growth.[6] A 30-60 second rest interval between sets suits hypertrophy training in many cases, although this can be individual, exercise, and muscle dependent.

Hypertrophy blocks often use a higher variety of exercises to train different muscle fibers and high volume training.

Strength

Maximal strength refers to a trainee's ability to produce maximal force. Maximal strength training mostly involves type II muscle fibers. Clients interested in strength training fall into two categories: trainees who want to be generally stronger in their daily life, and strength athletes like powerlifters, strongmen, and other athletes from mainstream sports.

Maximal strength training typically includes compound movements (movements in which multiple joints move at once) which involve as many muscle fibers as possible per exercise.

Maximal strength training involves lower volume than hypertrophy training, but high loads with 1-5 rep sets, but strength increases have been observed at working sets at or below sets of 20.[7] Strength training seems to be optimal when loads are at or higher than 80% 1RM, but significant strength gains can still be elicited at lower loads.[8]

3-5 minute rest periods (or longer sometimes) are best for maximal strength training physiologically and psychologically. Maximal strength training also benefits from high volume training depending on the trainees current mesocycle (see Periodization for more info).

Power

Power oriented goals center around the ability to produce a high degree of force quickly, handled by the type II muscle fibers.

Many athletes look into power training to maximize their speed and explosiveness during competition, but this specific style of training is not not recommended for novice lifters.

Novice lifters will often increase overall power during a strength or hypertrophy cycle, because those adaptations will stimulate some power increases in the de-trained. Olympic lifters use power training because their sport revolves around being explosive.

Like maximal strength training, multi-joint compound movements are preferred to build power. Power training uses either between 85-100% 1RM to improve force production or 30-40% 1RM to improve speed. Power training typically utilizes low volume, using sets of 1-3 reps with medium to high loads as fast as possible with good form. Rest intervals should be between 2-5 minutes for proper recovery between sets.[9] In many cases, power goals can also be considered the peaking phase in a program's periodization.

In many long term program designs, a trainer or coach will take their trainee through all of these phases at some point in 2 to 8 week periods called mesocycles (see Periodization). The main takeaway is that there is some overlap with all of these training goals. One will lead into another or will benefit another.

Subgoals

Subgoals can align with one of two of the more common goals. Many individuals have the desire to increase bone density, such as women at risk for osteoporosis. Resistance training positively correlates with improved bone density in randomized control trials.[10] In fact, any exercises with impact such as walking or running will typically benefit bone density.

The only exercises that do not benefit bone density are exercises like swimming or cycling which have low loads and no impact. While movements with impacts such as running or walking are beneficial for bone density, resistance training is more potent than cardiovascular exercises in increasing bone density.[11]

Clients may be interested in reducing injury. Resistance training has been shown to prevent acute and overuse injuries.[12] Targeted resistance reduces chronic pain more than other exercise intervention.[13] Increased muscle size and strength come with stronger denser bones and tougher connective tissue. Tendons and ligaments grow at a slower rate than muscle and bone, but they are benefited by training nonetheless. Strength training also reduces many forms of chronic pain. Chronic pain is often caused by muscle imbalances, which benefit from correctly trained muscles. Also, many people have inactive muscles or mobility restrictions from daily activities like excessive sitting, which can be corrected with a well balanced resistance training regiment.

For athletes of all kinds, speed, agility, and quickness (SAQ) is the focus. Again, all of the common training goals contribute to SAQ, but power training teaches the body to be explosive with each step or jump in generating speed. Resistance training improves connective tissue toughness and bone density to better resist the stresses placed on the body during sudden changes in direction. Plyometric training, or plyo training, also is benefitted by power training. Both plyo and SAQ training are explored further in other chapters.

Possibly the most common goal among most clients is weight loss. The most common strategy for weight loss includes a high degree of cardio, but resistance training can be extremely effective for long term weight loss and maintenance. Resistance training has been connected with decreases in obesity related conditions, but may not be the quickest way to reduce visceral body fat.[14] Basically, aerobic training may be the quicker path to weight loss, but resistance training correlates with overall better health outcomes in the long-term.

Particularly, as a trainee increases muscle mass, their base metabolic rate (BMR) increases, which helps long term weight loss and lowers obesity related health risks. The second benefit of hypertrophy training for weight loss is that the higher volume will burn more calories and help create the caloric deficit required for weight loss.

Client Type and History

Each kind of client may have different needs that will affect the way a trainer gets them to their goals. One client may have a knee injury while another may be older and have a heart condition. The type of client dictates how a program is designed outside of goals.

A client’s program may be dictated by their training age or experience. A program designed for a beginner will look vastly different to a program designed for a ten year veteran. A beginner may not understand how their body reacts to training and will usually be better off with a lower volume program. On the other hand, a training veteran may need a much higher volume training because that may be needed to stimulate growth.

Biological age is a major factor in designing a program for a trainee. Younger clients may be able to handle more volume and heavier loads because their body is in its prime. Recovery time for younger trainees is typically faster than older trainees. Older trainees may not be able to handle high weekly volume.

Assigning high volume to an older client may not allow them to recover and risk them developing injuries. Older clients may also not be able to handle as high an intensity as younger clients in some cases so it may be better to assign them higher rep exercises.

In conjunction with biological age, recovery capacity is a vital variable to consider. Recovery capacity includes nutrition habits, sleeping habits, daily stresses, age, and training experience all may affect recovery capacity. A trainee with high stress may not be able to recover from a high volume or high training frequency, while a client with all of these factors in order may benefit from a more intense program.

Injuries plague clients of all kinds and must be considered when designing a program. Injury history may dictate how much volume a trainee may be able to undertake for a certain body part. A trainee with a history of torn ACLs may not be able to do much, if any at all, leg exercises requiring high loads or large ranges of leg motion, while a trainee with a history of shoulder injuries may need to progress slower with their shoulder work than a trainee with perfectly healthy shoulders. Every injury requires its own considerations and adjustments.

As mentioned before, a client's lifestyle can affect their ability to recover and thus their ability to handle more intense training programs. However, some clients may have less time to train so this may affect their workout structure. Circuit training or supersets may be better for CEOs while pyramid sets may be better for professional athletes. A trainee with no equipment available will need a different program than one who goes to a gym on a regular basis.

Nutrition is a massive factor in a training program. A training program with an extremely high training volume will be wasted with poor nutrition. For example, college students often have poor nutrition habits and may not get the most out of their training programs.

Example Training Templates for Various Goals

Example Stability Program				
Body Part	Exercise	Sets	Reps	Rest
Chest	Stability Ball Push Up	3	15	1-2 minutes
Back	TRX row	3	15	1-2 minutes
Core	Plank	3	45 seconds	2 minutes
Legs	Bulgarian Split Squat	3	15	1-2 minutes

Example Muscular Endurance Program				
Body Part	Exercise	Sets	Reps	Rest
Legs	Goblet Squats	3	20	1-2 minutes
Back	Seated Cable Rows	3	15	1-2 minutes
Legs	Hamstring Curls	3	20	2 minutes
Chest	Incline Dumbbell Press	3	15	1-2 minutes

Example Hypertrophy Program				
Body Part	Exercise	Sets	Reps	Rest
Chest	Dumbbell Bench Press	4	10	1 minute
Back	Cable Rows	4	10	1 minute
Arms	Strict Bicep Curls	4	12	1 minute
Legs	Leg Press	4	12	1 minute

Example Strength Program				
Body Part	Exercise	Sets	Reps	
Shoulders	Overhead Press	4	4	3 minutes
Back	Pull Ups	4	4	3 minutes
Chest	Bench Press	4	5	3 minutes
Legs	Back Squat	4	5	3 minutes

Example Power Program				
Body Part	Exercise	Sets	Reps	
Chest	Weighted Plyo Push Ups	4	3	2 - 3 minutes
Legs	Squat Jumps	4	3	2 - 3 minutes
Core	Medicine Ball Slams	4	12	2 - 3 minutes
Post. Chain	Kettlebell Swing	4	12	2 - 3 minutes

Scheduling Workout Splits

When designing a template for a client or athlete to follow, consider both the client's scheduling limitations and their ability to recover from session to session.

The number of days trainees can workout (or want to workout) every week, the amount of time in those days, and the trainee's level of experience dictate the number of days in the microcycle (week of training) and the appropriate volume and muscle split used on those days.

Full Body Routines

Full body workouts are ideal for beginners, for trainees who have little time to train, and for people who want a low-level of training frequency per week. Clients using a full body routine can get the appropriate amount of training stimulus to enact big changes in their body with only 2 or 3 workouts per week.

Athletes often use this template, because sports-specific drills and practice takes up much of their weekly time. Full body splits involve training the entire body, using compound movements because of time and energy restrictions, each time the trainee works out.

Upper/Lower Splits

Upper and lower splits require the trainee to split up sessions between training their upper and their lower body. Intermediate-level exercisers often use upper/lower splits, because it allows them to focus more closely on individual body parts and train more often, although more advanced trainees may require a further split, like a push/pull/legs or individual body part split to achieve the maximal results. Exercisers in this model workout 2, 4, or 6 days per week depending on their goals and time availability.

Push/Pull/Legs

Push/pull/legs splits the body even further into 3 days of training. On day one, the trainee exercises the muscles which push (shoulders, chest, triceps), on day two they train the pulling muscles (back, biceps, forearms) and on day three they train their legs. Day four can either be a rest day or a repeat day where the client goes back to a push day.

Most trainers will never use this split with a client unless they train the client every day or trust that the client knows what they're doing and will workout diligently and safely on their own. This model requires a 3-days per week exercise cycle or 6-days per week.

Body Part Split

In this split, the exerciser trains individual muscles in every workout. This is a highly variable template and should only be used by advanced athletes and competitive bodybuilders to achieve maximal results.

Summary

Programming workouts requires the use of variables such as sets, reps, volume, intensity, rest, frequency, duration, and exercise selection. Fitness professionals should also consider the client's goals, as well as age, injuries, and training history.

Some goals will be able to coexist together in an exercise program as subgoals while others need to be placed on hold until the client achieves the primary goal. In addition, personal trainers should factor in the schedule of the client and level of experience when designing weekly templates for various body parts and movement patterns.

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Chapter 18

Periodization

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Introduction

The long-term success of a training program depends on progressing through multiple phases of training that target different, complimentary fitness goals that cycle over periods of time. Most large fitness goals cannot be achieved without multiple types of training.

However, this training must be planned and coordinated properly to successfully drive adaptations and avoid injuries. This long-term planning is called periodization and is a key knowledge requirement for successful fitness professionals.

Periodization is defined as the systematic manipulation of training variables in order to maximize training adaptations. This includes changes in exercise selection, loading schemes, sets, reps, and even exercise order.

Traditionally, periodization has been the domain of strength and conditioning professionals focusing on athletes, who have a defined “pre”, “mid”, and “off season.” However, the same principles of progression and periodization used to improve athletic performance apply to the general population as well.

Failure to properly periodize a client’s program leads to a stagnation of training adaptations at best and injury at worst. All training programs must balance the stimulus for adaptation with the level of fatigue acquired.

If the body were able to shed fatigue at a constant rate, while simultaneously adapting at a constant rate, then an optimal program could be established and practiced without variation indefinitely. However, the rate of adaptation varies over time.

Furthermore, the rate at which an individual recovers from fatigue is based on a multitude of factors. Hence the need to periodize programming to manage it optimally. This chapter focuses on the key physiological concepts related to periodization as well as periodization types and examples.

Periodization Hierarchy

Periodization is broken down into an organizational framework used to construct short, medium, and long term goals and plans.

The smallest time frame is the individual day or training session. At this level, the fitness professional develops the plan for the day, including exercise selection and daily programming variables.

Microcycles last several days to one week of training. The most common microcycle length is one week. At this level the trainer determines training volumes for the week, the number of sessions per week for each body part, and planned rest days.

The mesocycle ranges from 2—8 weeks, with the final week being an intentional deload. The trainer should structure mesocycles around specific goals, such as hypertrophy, strength, or endurance.

Two to three consecutive mesocycles with the same training goal but a change in training plan are referred to as training blocks. For example, a hypertrophy training block might include two or three mesocycles.

The longest duration subcomponent of periodization is the macrocycle, which is often an annual plan but not necessarily. Macrocycles include several mesocycles and transition from one goal to another, typically including at least one maintenance period. For example, a typical macrocycle may have two to three mesocycles of hypertrophy, followed by two to three for endurance, and lastly a few mesocycles for strength.

Some clients will require multi-year training plans to achieve long-term goals. These plans include multiple macrocycles with repeating goals and several maintenance phases. It is important to note that the duration of these periods is fluid, and should logically flow from the clients' contract duration and goals. The table below summarizes the periodization hierarchy.

Periodization Hierarchy

Period	Duration	Focus
Individual session	1-2 hours	Specific exercises, loading schemes, sets x reps, rest interval
Microcycle	1 week	Total training volume per muscle group
Mesocycle	3-6 weeks	Short term training goals such as hypertrophy, strength, endurance
Macrocycle	Several months to 1 year	Several mesocycles combined, usually ending with a maintenance period
Multi-year plan	2 or more years	Several macrocycles combined, usually with repeating goals, each ending with a maintenance phase

Another form of periodization is auto-regulated periodization which allows for individual sessions within a microcycle to vary based on client preparedness. Under this model, programming varies based on feedback from the client. A night of poor sleep or a sudden stressful event can be reasons to reduce training volume and/or intensity. On the other hand, if motivation is high and performance is better than expected, increasing volume or load can be warranted. In essence, the trainer must tailor the sessions' plan and goals based on the client's day to day abilities.

This method is vastly superior to forcing a pre-planned program irrespective of the client's feedback but note that it can get a bit messy in terms of quantifying progression and overall goals if the training is constantly shifting and the coach does not account for this when programming for the client.

Traditional vs. Undulating Periodization

Many textbooks and reference manuals title periodization strategies as "linear" and "nonlinear." However, in the strictest sense, both are nonlinear in nature due to the varying levels of training volume throughout a mesocycle of training. Therefore, the terms traditional and undulating will be used, as they are more descriptive.

Traditional periodization strategies involve training with the same sets and repetitions per microcycle, with variations in load per training day, for example a hard, medium, and light day.

Each successive microcycle would increase either the load or volume or both, resulting in a mostly linear increase in total training volume over the course of the mesocycle.

This would result in a work over time graph similar to the chart below:

Traditional Periodization

WEEK 1			
	Day 1	Day 2	Day 3
Program	4x10x100 kg	4x10x85kg	4x10x60kg
Total work	4000kg	3400kg	2400kg
WEEK 2			
	Day 1	Day 2	Day 3
Program	4x10x110kg	4x10x95kg	4x10x80kg
Total work	4400kg	3800kg	3200kg

An important characteristic of traditional training is that, despite the weekly or session to session variation, the program still has one focus such as hypertrophy or strength, but not both. All training days within the microcycle are still focused on that goal.

Nonlinear or undulating periodization is similar in so far as there are variations within the microcycle. However, these variations are larger and focus on different goals. For example, one day or training session may focus on hypertrophy, the next day on strength, and so on.

Since these goals have distinct programming guidelines, the sets, repetitions, and load ranges all may change on a session-to-session basis. The resulting changes in overall training volume are drastic. Consider the example below:

Undulating Periodization

WEEK 1			
	Day 1	Day 2	Day 3
Program	5x3x200kg (strength)	4x10x150kg (hypertrophy)	3x20x100kg (endurance)
Total work	3000	6000	6000
WEEK 2			
	Day 1	Day 2	Day 3
Program	5x3x210kg (strength)	4x10x160kg (hypertrophy)	3x20x110kg (endurance)
Total work	3150	6400	6600

Programming a periodized training plan for fitness clients is, in many ways, more challenging than for athletes. Athletes have a clearly defined preseason, in season, and off season, which can simplify the process of setting goals and creating timelines.

General population personal training clients do not have such a rigid structure. However, that does not mean a long-term training plan is unnecessary. In fact, it is even more necessary and can serve as a goal setting exercise to increase client motivation and retention. There are a few guidelines to consider:

1. **Limit consecutive mesocycles with identical goals to three or fewer.**

Varying the training stimulus is a good thing.[5] Training the same movements, at the same intensity, with the same goal for longer than three mesocycles (one training block) will likely lead to monotony and training staleness.

2. **Follow a strength period with an endurance period.**

Training for strength involves relatively high loads with lower training volumes. At the conclusion of a strength focused training block, the connective tissues have been stressed for several months and would benefit from a period of light loading to allow for recovery and adaptation. Endurance training, which involves relatively low loads, is ideally suited to allow for this recovery while continuing training.

3. **Precede a strength period with a hypertrophy period.**

As mentioned above, strength training requires relatively high loads, a hypertrophy training block serves to acclimate the muscles and connective tissues to moderate loading, making the transition to heavier loading smoother.

4. **Following a strength period with a maintenance period is recommended**

As mentioned, every two to three training blocks should be followed by a maintenance mesocycle. A logical placement for a maintenance mesocycle is after a strength block, when fatigue is high, soft tissues have been heavily taxed, and motivation for training may be low.

5. **Fat loss phases can accompany endurance and hypertrophy periods, but not strength**

Most personal training clients have fat loss goals, therefore it is the trainer's job to combine nutritional and exercise strategies in a way that maximizes the effectiveness of both. The energy deficit required for fat loss will impact exercise performance, especially when training for strength.

Endurance and hypertrophy training will suffer the least from the caloric deficit and are better choices to program during a fat loss phase.

Example of Periodized Training Plans

Example 4-Week Periodized Training Block for Beginning Muscular Endurance

Muscle Group	Total Working Sets Per Week	Repetition Range	Intensity As a Function of Maximum Repetitions
Chest	10	15 - 30	10 - 30
Upper back	10	15 - 30	10 - 30
Anterior Thigh	8	15 - 30	10 - 30
Posterior Thigh/Glutes	6	15 - 30	10 - 30
Calves	6	15 - 30	10 - 30
Arms	12	15 - 30	10 - 30
Core/Abs	10	15 - 30	10 - 30

Training volume should increase weekly, either by increases in load, sets, or repetitions. However, overall training volume must remain within the endurance range. Note that exercise order can vary from one mesocycle to the next, but maintaining the same exercises is optimal for beginners to maximize technique mastery.

Deload for 1 Week

Example 4-Week Periodized Training Block for Beginning Muscular Strength			
Muscle Group	Total Working Sets Per Week	Repetition Range	Intensity As a Function of Maximum Repetitions
Chest	10	1 - 6	1 - 6
Upper back	10	1 - 6	1 - 6
Anterior Thigh	8	1 - 6	1 - 6
Posterior Thigh/Glutes	6	1 - 6	1 - 6
Calves	6	1 - 6	1 - 6
Arms	12	1 - 6	1 - 6
Core/Abs	10	1 - 6	1 - 6

Example 4-Week Periodized Training Block for Beginning Muscular Hypertrophy			
Muscle Group	Total Working Sets Per Week	Repetition Range	Intensity As a Function of Maximum Repetitions
Chest	10	5 - 30	8 - 12
Upper back	10	5 - 30	8 - 12
Anterior Thigh	8	5 - 30	8 - 12
Posterior Thigh/Glutes	6	5 - 30	8 - 12
Calves	6	5 - 30	8 - 12
Arms	12	5 - 30	8 - 12
Core/Abs	10	5 - 30	8 - 12

Note: the total number of working sets per muscle group per week does not change, but the intensity increases and the repetition range widens.

Deload for 1 week

Example 4-Week Periodized Training Block for Beginning Muscular Power			
Muscle Group	**Total Working Sets Per Week**	**Repetition Range**	**Intensity As a Function of Maximum Repetitions**
Chest	10	1 - 3	1 - 3
Upper back	10	1 - 3	1 - 3
Anterior Thigh	8	1 - 3	1 - 3
Posterior Thigh/Glutes	6	1 - 3	1 - 3
Calves	6	6 - 8	6 - 10
Arms	12	6 - 8	6 - 10
Core/Abs	10	6 - 8	6 - 10

NOTE: Intensity should be split between power and speed work. The power work will be in close to maximal effort while speed work will be 20-40% 1RM. Isolation exercises are more suitable for higher rep sets.

Summary

Proper periodization allows clients to progress towards long-term, larger fitness goals while remaining injury free. Knowledge of periodization is one of the key skills fitness professionals must develop to be successful, particularly when training individual clients for ambitious fitness goals.

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Chapter 19

Principles of Plyometric Training

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Introduction

Plyometric training encompasses any movement or exercise activity that involves a rapid eccentric loading quickly followed by a rapid concentric contraction. Generally speaking, plyometric modalities involve some form of jumping, hopping, or skipping. Due to the range of beneficial adaptations that occur with proper plyometric training, fitness professionals should be familiar with the plyometric exercise technique and program design principles to safely and effectively integrate plyometric training into client programs.

Definition of Plyometric Training

Plyometric training is defined as any rebound activity that take advantage of the neuromuscular and physiological properties of the musculotendon unit. This rebound activity uses an eccentric contraction of the muscle that is rapidly followed by a concentric muscle action to increase force production.[1] The goal of plyometric training should be to increase the potential of the muscle to maximize force production in the shortest time possible.

Benefits of Plyometric Training

Plyometric training has benefits that include improving speed, agility, coordination, running economy, strength and peak power.[2] Studies show that plyometric training has a greater effect on vertical jump height and agility compared to sprinting.[3]

Rate of Force Production

Rate of force production is the time it takes to produce force in the muscle through a ballistic action.[4] In many sports and activities there is a need for quick force production to overcome an opponent, obstacle, or weight. Therefore, rate of force development (RFD) is an important variable to understand when considering plyometric training effectiveness and programming. Ballistic training, speed, and weightlifting at appropriate velocities can all improve RFD.[5]

Neural Adaptations that Affect RFD

When a movement or reflex is initiated, either the motor cortex or the central nervous system signals the motor unit to activate. At this point the motor neuron discharges, causing the muscle to contract.

Motor units have different sensitivities or thresholds that determine how fast an electrical charge should be sent to create a contraction.[4] High threshold motor units are sensitive to inputs and have the ability to create rapid muscle contractions. High threshold motor units are more dominant in type II muscle fibers.[4]

By utilizing plyometric training, the discharge rate from high threshold motor units and the efficiency of signals from the central nervous system and motor cortex increases to allow for rapid muscle activation and contractions.[4] The result is an increase in the RFD due to explosive training. Strength training combined with explosive movements can also greatly increase RFD in all ages. [4]

Reactive Strength Index

Reactive Strength Index (RSI) is a fairly accurate way of identifying the effectiveness of a plyometric training protocol. RSI is calculated by taking the jump height divided by the time on the ground or, alternatively, flight time divided by ground contact time.[6]

Ground contact time, defined as the time from the start of a jump to take-off, is an important variable to consider because this takes into account the eccentric, amortization, and concentric phases of a jump.[7] It has been found that RSI is highly related to eccentric RFD, peak power, jump height, and ground reaction forces.[7] RSI can be an efficient way to give more information related to multiple variables in plyometric training than jump height alone. If jump height goes up then RSI goes up, if ground contact time decreases then RSI increases.

Stretch-Shortening Cycle

The stretch-shortening cycle (SSC) is a concept described by different mechanical and neurophysiological models that explains how an eccentric loading or pre-stretch can lead to a concentric muscle action that has enhanced force production compared to the same movement performed without a pre-stretch.[1]

The two widely accepted models used to describe how the stretch-shortening cycle occurs are the biomechanical and neurophysiological model.

Biomechanical Model

In the biomechanical model, the muscle and tendon together are considered the musculotendon unit. When the musculotendon unit is rapidly and forcefully stretched, like in the pre-stretch of a counter movement jump, work is being performed through lengthening of the muscle and tendon. The work performed is then absorbed in the form of elastic energy by the stretched muscle and tendon.[8] This is called “potentiating the muscle.” The concept is similar to pulling a rubber band and then releasing it. There is elastic energy stored as the rubber band pulls back. When the rubber band is released from its stretched position, a greater force production is achieved.

Elastic energy releases when a concentric or shortening of the muscle happens following a pre-stretch. The magnitude, rate, and duration of a stretch will determine the amount of elastic energy that can be released to increase the force production of a musculo-tendon unit.[9] In other words, the larger and faster the braking force occurs, the more powerful and explosive the movement will be.

It is important to note that elastic energy from the muscle and tendon decreases the longer it takes to start a contraction. If a pause lasts more than one second, cross bridging in the muscle cell detaches and potential energy decreases dramatically.[10] When performing a plyometric exercise, it is important to rebound quickly to maximize the force that can be produced.

Neurophysiological Model

Muscle spindles are located in the intrafusal fibers of the muscle.[11] When there is a rapid stretch on the muscle, a deformation within the muscle spindle occurs.[9] The muscle spindle sends an electrical signal to the spinal cord that is returned to the muscle to generate a reflexive shortening or concentric action. The greater the rate and magnitude of the stretch, the greater the concentric action.[8, 10]

Another factor to consider is the Golgi tendon organ (GTO). The GTO is in the musculotendinous unit, which plays a protective role in preventing overstretching by contracting the antagonist muscle. For example, the quad is stretched rapidly and the hamstring contracts to limit further rapid stretching or damage to the quadriceps.

In plyometric training, the more the GTO is inhibited or turned off, the more muscle fibers can be utilized to generate force and create stiffness or pre-activation of the agonist muscle to allow for a greater force return.[8] Plyometric training helps to desensitize the GTO.[9]

There is a pre-activation that occurs in the eccentric or stretching phase of a movement. This occurs because as a muscle stretches rapidly, other muscles are activated to slow the stretch and stiffen a limb for action.[10] Time and angle of movement affect how much force pre-activation of the muscle contributes to the movement.

The stretch shortening cycle contributes to force production due to pre-activation of the leg muscles before a jump, a stretch-reflex that occurs with the nerves, a recoil of elastic energy of the musculotendinous unit and the amount of cross bridges in the eccentric phase in the muscles fiber.[12]

There are 3 stages that explain how the stretch shortening cycle is used in explosive movements. These are the eccentric, amortization, and concentric stages.

Eccentric

An eccentric phase of the stretch shortening cycle requires a pre-stretch, also referred to as a braking or eccentric action of an exercise. The eccentric phase begins when force is generated into the ground to prevent a free-fall downward.

During this phase, elastic energy is stored into the muscle and tendon as it is stretched. The more eccentric or braking force generated, the greater the rate of concentric force for the jump.[7]

In addition, at this stage there is a reflex created in response to a rapid stretch on the muscle. This reflex is a stimulated muscle spindle that sends information to the spinal cord. Think of jumping, once lowering into the jump, eccentric forces are created to allow for a controlled fall versus a free fall. The faster and more forceful the drop, the more power is created.[9,10]

Amortization

After the eccentric phase there is a delay in the signaling from neurons before a concentric action occurs, known as “amortization.” Amortization is an isometric or static contraction that occurs before a concentric contraction of the muscle can occur. For example, in a countermovement jump, this is when the body is as low as possible right before propulsion.

In this stage, pre-activation of the muscle has been created from the eccentric phase to generate stiffness in the muscle and joint.[8,10] The longer the delay in this stage, the more energy that will be lost towards force production.[9] Both leg stiffness and neural feedback enhancements are critical to increasing performance.

Concentric

A concentric action of the muscle is a shortening of the muscle. If there is a concentric action immediately following the eccentric action, then an increase in force production occurs to create propulsion or flight. The increased force production at this stage comes from elastic energy released from the musculotendinous unit (biomechanical model) and the reflex action of the muscle spindles (neurophysiological model).[9]

Plyometric training is used progressively to allow for increased excitation of high threshold motor neurons, increased leg stiffness prior to a jump, a decrease in GTO sensitivity, and enhanced feedback from the central nervous system (CNS) to create enhanced performance.[8,9] When programming plyometric exercises, manipulation of different variables allows for overload and increased performance.

Exercise selection, frequency of training, volume of training, recovery of training and intensity of training are all important considerations.

It has been shown that there is no difference between volume, intensity or a mix of volume and intensity progressions on countermovement jumps (CMJ), squat jumps, sprinting and agility.[3] Therefore, if there is progression in volume and intensity using appropriate variable recommendations, performance can be improved.

Plyometric Training Variables

Variable	Description	Recommendations
Exercise selection	The type of movement	Bilateral to unilateral, goal specific
Length of training	Program duration in weeks	7-12 weeks
Frequency of training	Training days per week	1-2 days/week
Volume of training	Number of ground contacts per session	Beginner: 60 ground contacts Intermediate: 80-120 ground contacts Advance: 120+ ground contacts
Recovery of training	Rest in between sessions, sets, and reps	Intersession recovery: High intensity session: 48-72 hrs Low intensity session: 24 hrs Inter-set Recovery: 60-240s
Intensity	The amount of ground reaction force, torque, and RFD needed to perform an exercise	Initial intensity determined by exercise selection, increase intensity by 9-12% when progressing a specific exercise

Exercise Selection and Selection Progression

Plyometric training should start with bilateral and work to unilateral in lower limb exercises as experience increases.[13] There is a greater demand on the body from single leg jumps that require an adequate amount of strength and biomechanical efficiency.

When considering horizontal plyometric exercises like bounding, adequate technique in vertical jumps should precede horizontal jumps.[13]

Some exercises are ideal for the sport or goal. For instance, horizontal plyometric exercises are more beneficial to improve sprints.[14] For an increase in vertical jump, a combination of exercises like depth jumps, squat jumps and CMJ seem to be better than one single exercise alone.[15]

Length of Training

7-12 weeks of plyometric training is recommended to allow for an effective increase in jump performance, sprint performance, strength, and contact time.[16,17]

Frequency of Training

Plyometric training should be performed 1-2 times per week to increase performance. It seems that with moderately trained athletes, using high intensity exercises one session per week for seven weeks is enough to induce changes, with two per week being optimal.[16]

Plyometric training volume is based on the number of contacts with the ground. These contacts can be counted from multiplying sets by the total number of reps. For example, when performing 1×6 tuck jumps and 2×5 hurdle jumps, the total ground contact would be 6 + 10 = 16 ground contacts.

Technique and experience should be considered when determining the volume needed in a program. More is not better in plyometric training. There seems to be an optimal amount of volume that allows adaptations and performance to occur.[2]

Session Volume Ground Contacts

Beginner

An optimal amount of ground contacts for beginners is 60 ground contacts per session; however, to generate greater benefits in sprint performance, higher volume is recommended.[18]

Intermediate

For more intermediate athletes, programming 80-120 contacts per week has been shown to be effective for increases in performance.[19,20]

Advanced

For more advanced athletes it is recommended that 120 or more ground contacts be made per session.[15] It is important to note that more volume does not seem to be beneficial to enhance performance.[2]

Extraneous volume may have the same benefits as a lower volume of ground contacts, therefore, it is advised to stay between 120-198 ground contacts per session for advanced athletes.[2,15]

Rest Period

Research suggests that 240 seconds in between sets and 30 seconds in between repetitions elicits the most beneficial adaptations.[19] However, for practical purposes, as little as one minute between sets and little rest between repetitions has been found to allow sufficient recovery with 3 sets of 10 using 30% of body weight in a loaded countermovement jump.[21] Age may influence the recovery time of plyometric sets, with adolescents 8 to 14 needing lower rest times between sets of 30-120 seconds.[18]

Available training time, volume, intensity and fitness level should all dictate how long recovery between sets should be.

Recovery

Adequate recovery between plyometric sessions is needed based on the intensity, volume, age, and experience of the athlete. High intensity sessions should have at least 48 to 72 hours of rest between sessions and low intensity sessions need at least 24 hours of rest.[20]

Intensity

Intensity in plyometrics depends upon the amount of ground contact force, the rate of force development needed to execute the movement, and the torque on the joints during the landing.

Intensity should always be specific to the training goal. For example, a basketball player may need to increase vertical height, but a runner might need to increase muscle efficiency at lower intensities to preserve energy.

High intensity plyometric drills include depth jumps, single leg jumps, and broad jumps. Low intensity plyometrics exercises consist of skipping, double leg bounces, and countermovement jumps (CMJ).[3]

Example of Intensity Progression

Progressions in training intensity of 9-12% are considered appropriate.[23]

To increase a depth jump difficulty, the height can increase from 20 cm to 22 cm (a 10% increase). The distance of a single leg jump can go from 3 feet to 3.3 feet (10% increase). Exercises like A-skips could be progressed into power A-skips where height is the focus.

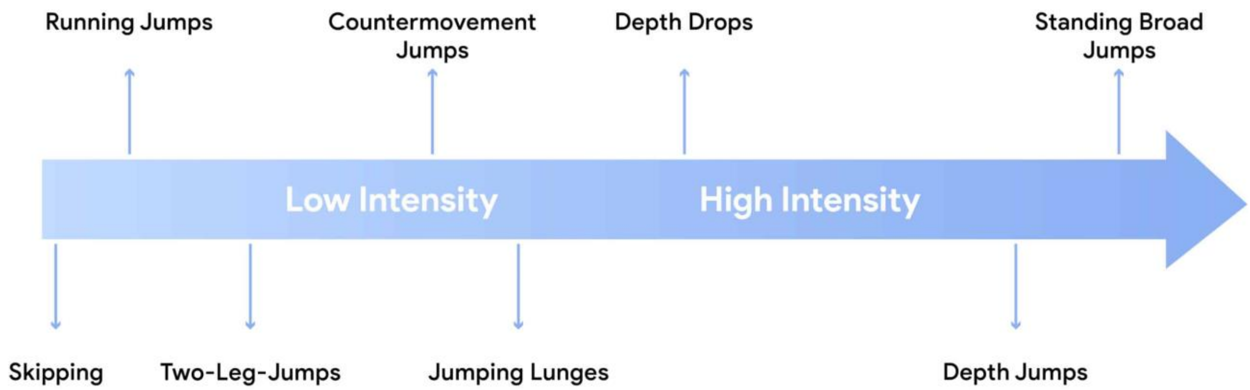

Figure adapted from Lievens M, Bourgois J, Boone J. Periodization of Plyometrics: Is There an Optimal Overload Principle?

Use of Weighted Jumps

The purpose of using a weighted jump is to increase power development in the lower limbs, specifically, peak power development or the greatest amount of power that can be achieved. Increasing the intensity of jumps using weights requires proficient technique in jumps unloaded before loaded.

When considering the mode of exercise to use with weighted jumps, greater peak power has been shown to be generated with a hexagonal barbell or trap bar at arm's length when compared to a barbell.[24]

With a hexagonal barbell, the weight should be between 10-20% of 1-RM box squat (box height set to where legs are parallel to the floor).[24]

Loaded jumps do take away from the SSC cycle (stretch-shortening cycle) because of longer ground contact times.[15] Therefore it is highly recommended that there is an intermediate to advanced level of efficiency in unloaded plyometric training to maximize the effectiveness of weighted jumps.

Plyometric Technique for the Select Exercises

Squat Jump

Difficulty: low

Exercise Instructions:

1. Lower hips to right above the knee line while maintaining an upright torso.
2. Explosively extend ankles, knees and hips until legs are off the ground.
3. On landing, contact the ground with toe to heel landing while keeping torso over the hips and knees bent to create a soft landing.

Butt Kick

Difficulty: low

Exercise Instructions:

1. Begin running forward or in place.
2. Relax the ankle and "flick" the heel of each foot back towards the glutes. The knee should be slightly forward of the hips.
3. Landing is based on running mechanics, but usually consists of a toe or mid-foot landing that is capable of "springing the other foot off the ground."

Multiplanar Jump with Stabilization

Difficulty: low

Exercise Instructions:

1. Stand upright then initiate the movement by bending at the knees and dropping weight rapidly into a ¼ squat position. Knees and toes face the same direction and knees bend at the same time the hips drop.
2. Rapidly extend hips, knees ankles to triple extension until feet leave the ground. Look at 90 degrees from your starting position and rotate body into a new direction while in midair.
3. Decelerate body on landing with hips, knees and toes facing the same direction and hold in the squat landing position for 1-3 seconds.

Multiplanar Box Jump-Down with Stabilization

Difficulty: medium

Exercise Instructions:

1. Stand on top of a box.
2. Step one foot off the box and drop without jumping.
3. Toes, knees and hips face the same direction upon landing with knees aligned with hips and slightly bent over the shoe laces (not faced inward).
4. Hold the landing squat position for 1-3s.

Lunge Jump

Difficulty: medium (no leg switch in air), high (switching legs midair)

Exercise Instructions:

1. Begin with one foot forward, and one foot back. Width between feet should mirror an athletic stance. Rear foot will be far enough back to allow the rear leg knee to drop underneath the hip. Rear foot heel will be off the ground and bottom of toes will be pushed into the ground. Rear foot will have 20% of body weight. Front foot will have 80% of the weight and will have toes facing forward and heel flat on the ground.
2. Bend at both knees and use hands to rapidly extend knees, ankles, and hip into the air. For increased intensity switch legs in mid-air. The same foot that was in the front starting should be in the rear.
3. Absorb the impact of landing by bending the knees as the body touches the ground. A toe to heel landing of the front foot should occur and the same time the "balls of the feet" landing on the rear foot happen.

Tuck Jump

Difficulty: medium

Exercise Instructions:

1. Initiate the movement by bending at the knees and dropping weight into a ¼ squat.
2. Rapidly extend ankles, knees, and hips into triple extension until feet leave the ground. As the body reaches maximal height tuck the knees into the chest.
3. As the body prepares for landing, “unwind” the legs from the chest rapidly and create a “soft landing” by creating a toe to heel contact with the ground and bending the knees to “absorb” impact.

Repeat Box Jumps

Intensity: high

Exercise Instructions:

1. Initiate movement by bending from the knees on the ground in front of the box and rapidly lowering the body into a ¼ squat.
2. Immediately extend the ankles, knees, and hips into triple extension until propulsion off the ground is created. Create soft landing contact with the box and do not stand up completely.
3. Use a rapid, spring-like contact with the box to quickly bring feet back off the box back to the ground where the athlete started. Repeat the desired repetition box jumps as quickly as possible with no rest.

Power Step-Up

Difficulty: high

Exercise Instructions:

1. Initiate the movement by bouncing or hopping on one foot while simultaneously flexing the contra-lateral hip (opposite side of the body from flexed hip) to 90 degrees. The opposite arm chops up simultaneously with hip flexion.
2. Drive flexed hip down and underneath the hips until both feet bounce off the ground at the same time. Simultaneously both arms extend toward the floor.
3. Forcefully bounce off the ground for height with the opposite leg while rapidly driving the contra-lateral leg into hip flexion at 90 degrees. The opposite arm chops up simultaneously with hip flexion. Repeat the second step.

Skaters

Difficulty: high

Exercise Instructions:

1. Initiate the movement by pushing off the outside leg while simultaneously bending the inside leg to prepare to jump.
2. Swing the outside leg behind the front leg while preventing rotation of the hip and keeping shoulders over the hips.
3. Land softly with the front foot in contact with the ground, toes forward, knees aligned with the toes, and "belly-button" forward. There should be no rotation in the hips.
4. Swing the rear leg behind and forward while simultaneously pushing off the ground. Landing mechanics are the same as above.

Single Leg Power Step Up

Difficulty: high

Exercise Instructions:

1. One foot will be on a box and the other foot will be underneath the hips on the ground and flat.
2. Using the foot that's on the box (not the rear foot), forcefully and rapidly extend the hips and ankle until standing upright. Hips, knees, and ankles should be extended, and rear foot should be off the ground.
3. Upon landing, absorb the impact by bending the back leg and lower rear foot back to the ground to the starting position.

Depth Jump

Difficulty: high

1. Start standing on a box between 4 and 20 inches. Reach one foot out in front and drop onto the ground. Do not jump off the box.
2. Bend the knees to absorb the landing on the ground, and spring back up as quickly as possible into a jump with the goal of achieving maximal height.

Ballistic Push Up

Difficulty: high

Exercise Instructions:

1. Initiate the movement by starting into a plank with palms flat on the ground, elbows extended, knees extended, glutes squeezed, and abs flexed.
2. Drop chest to the ground rapidly and then execute a forceful, powerful push-up with the goal of both hands coming off the ground.
3. Allow the upper body to be absorbed into the ground to allow for rapid execution of another ballistic push-up.

Summary

Plyometric training encompasses any rebound activity that take advantage of the neuromuscular and physiological properties of the musculotendon unit such a rebounding, jumping, hopping. Plyometric training has benefits that include improving speed, agility, coordination, running economy, strength and peak power.

It involves the stretch-shortening cycle, and includes eccentric, amortization, and concentric phases. Intensity, volume, frequency, and exercise selection are all based around the level of trainee.

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Chapter 20

Principles of Speed, Agility, and Quickness Training

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Introduction

Speed, agility, and quickness (SAQ) are athletic performance-based skills that offer a variety of benefits to both athletes and the general fitness population alike.

Fitness professionals must be familiar with the concepts, techniques, and programming guidelines for SAQ training to offer these modalities as part of a comprehensive fitness program.

In the context of training general fitness clients, SAQ drills can be beneficial for a variety of client types. SAQ training should not replace resistance training in most situations but can be included in conjunction with resistance training.

Clients who engage in recreational sports can benefit tremendously from SAQ training, and it also provides additional variety and stimulus to a client's training plan, regardless of their fitness goals.

The sub-skills in SAQ are distinct but related and should be progressed logically and appropriately to drive desirable adaptations.

SAQ Training Concepts

To understand SAQ training there are key concepts to understand as they will be an influencing factor in any SAQ training program.

Most SAQ movements can be broken down into three phases: acceleration, maximum speed, and deceleration.

Acceleration

In physics, acceleration refers to the rate speed increases with respect to time. In the context of SAQ, acceleration is the phase of a drill involving going from stopped or low speeds to maximal velocity.[1]

Maximum Speed

Maximal speed is the point during a sprint at which maximal power output is generated that results in the body moving horizontally at the maximum possible speed the individual can reach.[2] Maximal speed is not necessarily reached during all SAQ drills, as for certain drills the distance covered is too short to achieve true peak speed.[1]

Deceleration

In physics, deceleration (also called negative acceleration) refers to the rate at which speed decreases with respect to time.[1] In the context of SAQ, deceleration involves the act of reducing speed, often in preparation for a change of direction.

Deceleration places a high degree of eccentric force on the body, and can also result in a plyometric effect when rapidly re-accelerating in another direction.

Ground Reaction Forces

Ground Reaction Forces (GRF) is the force exerted by the ground against the human body when the body is in contact with the ground.[2] In SAQ, contact force is applied by the exerciser's feet to the ground, and the ground reaction force pushes back against the feet.

When standing still, the ground reaction force will equal the force of gravity pulling the individual's body toward the Earth. During acceleration, sprinting, and deceleration, ground reaction forces exceed the normal gravitational force on the body.[3]

Changes of direction occur frequently during most field sports, with professional soccer players often performing 600-700 changes of direction per day.

In the context of general fitness, change of direction skills are helpful for clients who engage in recreational sports to improve performance and reduce injury risks, assuming proper form is followed.

Rate of Force Development

As discussed in Principles of Plyometric Training, the rate of force development (RFD) is a measure of how quickly the body can generate force.

RFD is influenced by a variety of factors including muscular strength and neural drive. Timed performance on SAQ drills will improve if RFD is improved, all factors remaining equal. Improvements to rate of force development are brought about through progressive SAQ training as well as resistance training and plyometric training. For maximum improvement to RFD, a combination of resistance, plyometric, and sprint training should be employed.[5]

Stretch Shortening Cycle

SAQ has a substantial plyometric component, and the stretch shortening (SSC) cycle plays a major role in the force production during SAQ activities.[5] Improvements to the SSC result in greater force production when acceleration rapidly follows deceleration.

The deceleration is the eccentric component, the brief isometric contraction during the change of direction is the amortization phase, and finally, reacceleration forms the final concentric phase of the SSC during SAQ.

Sprinting

Sprinting refers to the activity of running at maximal speed and its associated training protocols. Sprinting ability can be improved through a variety of training methods including resistance training as well as sprinting protocols.

Given the requisite intensities required to reach maximal speeds, sprinting is a predominantly anaerobic activity, relying on the ATP-PC and anaerobic-glycolytic systems.

Sprint speed is the result of two factors: stride length and stride rate.

Stride length is the distance covered between two strides. Stride rate is the number of strides taken with respect to time.[6]

Each individual will have an optimal stride length as determined by their individual biomechanics. If a client has proper sprint form, then increasing stride rate, as opposed to stride length, is the best approach to improve speed.

Research also shows that increased stride rate with a reduced relative stride length reduces the risk of many common running injuries.[17]

Depending on a client's training experience, improvements to strength and power brought about via resistance training and plyometric training will result in improved sprint speeds.

As an individual adapts to an initial training program, the training will need to favor speed-specific activities if continued improvements in sprinting ability are desired.

Sprint Mechanics

Each part of the human body along the kinetic chain has a specific role in allowing the human body to successfully sprint.

The posterior kinetic chain of the body is responsible for hip extension and acts as the driver for linear maximal force production, propelling the body forward.

The anterior kinetic chain aids in triple extension with the quadriceps acting on the knee and hip/pelvic stability through core stabilization.[6]

More specifically, during a sprint, the foot and ankle act as a spring, absorbing and redistributing energy while running.[8] Additionally the plantar flexors aid in forward propulsion, particularly during the acceleration phase.[11]

The knee works as a shock absorber while sprinting by flexing to absorb impact forces and redistribute them throughout the kinetic chain.[9] Additionally, the knee works in concert with the ankles and hips creating triple extension or full extension of the 3 joints. Triple extension is vital in running to optimize stride length and force development.[9]

The lumbopelvic hip complex produces maximal force through hip extension.[10] It further improves sprint performance by flexing to increase knee drive. The greater the knee drive the higher the gravitational force that can be produced upon planting the leg.[10]

During acceleration, the sprinter will be in a forward leaning position, slowly raising the torso and coming upright as they approach maximal speed.

During the maximal speed phase of a sprint, the head should remain level and in line with the spine.

This positioning allows for elongation of the spine, prevents injury from potential asymmetry, and can improve mental performance.[12]

Change of Direction and Agility

Change of direction and agility are often thought of as interchangeable terms, but they are distinctly different skills, despite some overlap.

Change of direction refers to the body's ability to move from one direction to another safely and efficiently. COD can be broken into phases of deceleration (eccentric contraction), plant (isometric contraction), and acceleration (concentric contraction).[3]

Examples of change of direction include turning the corner at a base or taking an otherwise preplanned route that involves at least one directional change.

Agility involves changing direction in response to a stimulus, such as cutting left in response to a defender cutting right during field sports. Because agility requires rapid decision making before action, it has an entirely separate neurological component.

Additionally, recent meta-analysis draws attention to the fact that individuals in live sport scenarios often change their movement patterns when actively preparing for and responding to opposing players as opposed to performing pre-planned routes.[18]

The change in movement pattern during live play means that performance on pre-planned change of direction routes may not correspond to relevant neurological agility benefits.

In terms of general fitness training, incorporating a stimulus and response into a change of direction activity is a straightforward way to add the agility component. This type of training can be particularly beneficial for older adults when it comes to reducing the risk of falls as well as many of the other beneficial adaptations associated with resistance training.[19]

Examples of agility activities for general fitness include ‘stop-and-go’ activities as well as changes of direction to the left or right depending on a sound or color signal displayed by the coach.

Benefits of SAQ Training

Specific SAQ training is designed to challenge neuromuscular systems and body control.[13] This training enhances not only speed, agility, and quickness but can lead to the following beneficial adaptations:

- Increased force and power production[14]
- Injury prevention through increased body awareness and reaction time[15]
- Increased muscular strength endurance[16]
- Reduced risk of falls and other injuries in older adults[19]
- Weight loss

SAQ Training Progressions

For the beginner athlete SAQ designs should initially start with 2-3 repetitions of an exercise with lengthy rest between repetitions. The exercises should limit the total number of changes of direction but gradually add variables over time.

1. Fast feet for 30 seconds rest for 60 seconds for 2-3 sets
2. One-ins ladder drill 2 repetitions per side for 2 sets resting for 60 seconds between sets.
3. Two-ins ladder drill 2 repetitions per side for 2 sets resting 60 seconds between sets.

The intermediate fitness participant should have a greater sense of body awareness and overall fitness allowing for more variables to be included into the programming:

1. In-in-out-out ladder drill for 4-6 repetitions, 2 sets, and up to 60 seconds rest between sets.
2. Ali shuffle ladder drill for 4-6 repetitions, 2 sets, and up to 60 seconds rest between sets.
3. T-drill for 3-5 repetitions, 2 sets, and up to 60 seconds rest between sets.
4. Box drill for 3-5 repetitions, 2 sets, and up to 60 seconds rest between sets.
5. 5-10-5 drill for 3-5 repetitions, 2 sets, and up to 60 seconds rest between sets.

The advanced fitness participant could use a program that focuses on power production which necessitates a longer rest interval due to the demands place on the body:

1. Sprints, 40 meters, 4 repetitions, 2 sets with up to 90 seconds rest between sets.
2. Depth jump to forward run, 5 repetitions, 2 sets with up to 90 seconds rest between sets.
3. Modified box drill, 4 repetitions, 2-3 sets, with up to 90 seconds rest between sets.
4. Z-drill, 4 repetitions, 2-3 sets, with up to 90 seconds rest between sets.
5. T-drill, 4 repetitions, 2-3 sets, with up to 90 seconds rest between sets.

If introducing SAQ training to special groups certain steps should be taken to maximize the benefits of SAQ training.

SAQ programs designed for youth participants carry similar benefits in terms of strength increases and increased body control.[14,15]

Specific design considerations include:

- Gamifying by playing tag or jumping rope to keep the entertainment value high.
- Consider the youth participant along the lines of the beginner programming by limiting changes of direction/complexity initially and building as body awareness grows.

SAQ programs for seniors carry the same health benefits as all ages however the focus is different. For senior populations the focus is less on utilizing speed and power exercises and more so on training activities that improve activities of daily life. Example exercises include:

- Hurdle step overs.
- Cone obstacle courses at a walking pace.
- Sit-to-stand movements.

SAQ programs designed specifically for weight loss should focus on the high intensity interval aspect of SAQ.

High intensity movements for short periods with adequate recovery have been shown to be an effective weight loss training technique.

Any combination of exercises can be effective following the interval model with a focus of elevating the heart rate then allowing recovery.

A-Skip

Difficulty: Low

Exercise Instructions:

1. Begin standing with feet hip-distance apart and torso upright.
2. Raise one leg to hip height while skipping on the ball of the opposite foot.
3. Place raised leg down directly under your center of mass momentarily standing on both feet while they are slightly staggered.
4. Repeat steps alternating legs while moving forward.

Additional Notes:

- Maintain posture to avoid forward or backward leans.
- Engage arms in opposition of elevated legs.
- Avoid twisting.
- Find a comfortable pace and rhythm.

Agility Addition:

- Add stop and go in response to light or sound signal from coach.

Fast Feet

Difficulty: low

Exercise Instructions:

1. Start standing with feet hip width apart.
2. Pushing through the balls of the feet, run in place quickly.
3. Continue for desired time or repetitions.

Additional Notes:

- Can be performed moving forward by taking as many steps as possible over a set distance.
- Breathe deeply throughout the movement creating a steady rhythm.
- Use your arms in rhythm with your feet.

Agility Addition:

- Add stop and go in response to light or sound signal from coach.

Sprints

Difficulty: high

Exercise Instructions:

1. Following a proper warmup and practice sprints at a lower intensity level prepare for the first all out sprint.
2. Determine start and finish line for the next sprint.
3. Start position can be standing with feet staggered or in a track stance depending on the goal of the exercise performer.
4. On the predetermined signal to start, performer takes off in a run at maximum speed and maintains effort until crossing the finish line.

Additional Notes:

- Run tall with head, neck, and shoulders in line with hips.
- Arms should move only in the sagittal plane avoiding crossing over the body.
- Elbows should be bent to 90 degrees.
- Feet should land directly underneath the torso on the ball of the foot.
- A high heel lift off and knee pull through should be emphasized.

Agility Addition:

- This is not recommended if training for maximal speed.

Deceleration Drills

Deceleration drills have a single focus on the eccentric phase of a movement or the slowing down of a concentric movement. Drills can be implemented across the kinetic chain for any movement that requires a change or stop in momentum. Additionally, the difficulty of deceleration drills can gradually increase by changing or adding planes of movement, progressing from bipedal to single stance activities, or adding external load/forces.

Example exercises include depth jumps, sprint to backpedal, drop and catch drills, and single leg lateral hop to balance.

Depth Jumps to Forward Run

Difficulty: high

Exercise Instructions:

1. Start standing on an elevated surface.
2. Either step or lightly hop off elevated surface emphasizing landing on two feet in an athletic stance.
3. Immediately drop into a squat to slow momentum from the drop.
4. As soon as possible, explode forward into a forward run.

Additional Notes:

- Emphasize quick and controlled ranges of motion.
- Maintain good posture and eyes up while landing.

Agility Addition:

- Run forward, cut left, or cut right upon landing in response to auditory or visual stimulus.

Speed Ladder Drills

Agility Addition for Speed Ladder Drills: stop and go or change drills in response to light or sound signal from the coach.

One-ins

Difficulty: low

Exercise Instructions:

1. Start standing at the beginning of a speed ladder in an athletic stance with feet hip width apart.
2. Movement will begin in a controlled run by quickly placing the first foot inside the first box of the speed ladder.
3. Continue running, placing the opposite foot inside the second box of the speed ladder.
4. Progress through the ladder in a controlled run placing only one foot inside each box and alternating feet.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.

Two-ins

Difficulty: low

Exercise Instructions:

1. Start standing at the beginning of a speed ladder in an athletic stance with feet hip width apart.
2. Movement will begin in a controlled run by quickly placing the first foot inside the first box of the speed ladder.
3. Continue running placing the opposite foot inside the same box of the speed ladder so that both feet are inside the first box.
4. Progress through the ladder in a controlled run placing both feet inside each box.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.

Side shuffle

Difficulty: low

Exercise Instructions:

1. Start standing at the beginning of a speed ladder while facing sideways in an athletic stance with feet hip width apart.
2. Movement will begin in a controlled lateral shuffle by quickly placing the first foot inside the first box of the speed ladder.
3. Continue moving laterally by placing the opposite foot inside the same box of the speed ladder so that both feet are inside the first box.
4. Progress through the ladder in a controlled shuffle placing both feet inside each box.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.
- Emphasize upright posture and eye level staying off the floor.

In-in-out-out

Difficulty: low-medium

Procedure:

1. Start standing at the beginning of a speed ladder, with feet on either side of the first box.
2. Movement will begin by quickly placing the first foot inside the first box of the speed ladder followed immediately by the second foot.
3. Weight and impact should be on the balls of the feet.
4. Step forward and out placing the first foot outside of the second box.
5. Repeat with the opposite foot.
6. Progress through the ladder repeating both feet inside each box then outside the next box.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.
- Emphasize upright posture and eye level staying off the floor.

Zigzag

Difficulty: low-medium

Exercise Instructions:

1. Start standing at the beginning of a speed ladder, with both feet in front of ladder and off to one side of the first box.
2. Movement will begin by quickly placing the foot nearest the ladder inside the first box. The step should be forward and lateral.
3. Immediately follow with the second foot.
4. Weight and impact should be on the balls of the feet.
5. Step first foot laterally outside of the second box.
6. Repeat with the opposite foot but instead of planting the second foot only tap the toes on the ground maintaining bodyweight on the first foot.
7. Move the second foot forward and lateral to plant inside the second box.
8. Repeat the above steps to progress through the ladder.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.
- Emphasize upright posture and eye level staying off the floor.
- Movements into the ladder should be forward and lateral.
- Movements out of the ladder should just be lateral.
- Add a challenge to the drill by having fitness participant perform the move in reverse.

Ali shuffle

Difficulty: medium

Exercise Instructions:

1. Start standing at the beginning of a speed ladder, standing with feet together facing the side of the first box.
2. Movement will begin by quickly hopping into a staggered stance while placing the lead foot inside the first box.
3. Trailing foot should be planted slightly behind the body and outside of the first box.
4. Perform another hop moving slightly laterally placing lead foot outside of the second box and trailing foot inside of the first box.
5. Weight and impact should be on the balls of the feet.
6. Repeat the above steps to progress through the ladder.
7. Each foot should alternate being placed inside of each box.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform at a fast but controlled pace.
- Perform drill multiple times alternating starting foot.
- Emphasize upright posture and eye level staying off the floor.

5-10-5 Drill

Difficulty: medium-high

Exercise Instructions:

1. Start with a 5-10-5 grid. Place 3 sets of cones in a row with each set 5 yards from the last. Each set of cones should be 5 yards apart from its partner.
2. The fitness participant will start at the middle set of cones with their hand touching the line between the pair of cones.
3. The fitness participant will choose a direction to begin the drill.
4. At the start of the drill, the fitness participant will sprint the 5 yards from the middle cones towards the outside set of cones they chose to begin with.
5. Once they reach the outside cones, they will touch the line between the pair and immediately change direction.
6. Then they will sprint the full 10 yards to the opposite set of outside cones.
7. Again, they will touch the line between the second set of outside cones, then immediately change direction and sprint back towards the opposite set of outside cones.
8. Drill ends when the sprint through the middle cones not stopping to touch the line between the middle pair.

Additional Notes:

- Perform drill multiple times alternating starting direction.
- Timing begins when the fitness participant starts moving and ends when they cross the middle cones for the second time.

Agility Addition:

- Change directions in response to auditory or visual stimuli.

Modified Box Drill

Difficulty: high

Exercise Instructions:

1. Start by creating the modified box grid out of 5 cones. 4 of the cones should create a square that is 5 yards long on each side with the 5th cone being placed in the center of the square grid.
2. Starting position can vary to adjust difficulty with the start and end drills.
3. The fitness participant will maintain their hips facing forward throughout the drill and must always repeat the pattern of corner cone-middle cone–corner cone until they cover the entire box.
4. The participant starts at the front right cone.
5. At the start of the drill, the fitness participant will reverse diagonal shuffle to the middle cone then forward diagonal shuffle to their starting cone.
6. Next, they will lateral shuffle to the front left cone and repeat the shuffle to the middle cone.
7. Upon returning to the front left cone, they will backpedal to the back left cone.
8. After shuffling to the middle cone and back they will lateral shuffle to the back right cone.
9. After shuffling to the middle cone and back they will sprint to the front right cone and come to a complete stop at their starting position ending the drill.

Additional Notes:

- Perform drill multiple times alternating starting position.
- Timing begins when the fitness participant starts moving and ends when they return to their starting position.

T-Drill

Difficulty: Medium

Exercise Instructions

1. Start by creating the T-Drill grid utilizing 4 cones or markers. The first cone will be used at the starting and ending point. The second cone should be placed 10 yards away in a straight line from the first cone. The third and fourth cones should be placed 5 yards away to the right and left of the second cone. The four-cone grid should resemble a capital T.
2. The fitness participant should start in an athletic stance at cone one facing cone two.
3. When the test starts, the fitness participant will run from cone one to cone two as fast as possible but under control so they can touch cone two with one hand.
4. The fitness participant will then laterally shuffle to cone three again touching the cone with one hand before changing direction and laterally shuffling to cone four.
5. After touching cone four, the fitness participant will shuffle back to cone two.
6. After touching cone two a second time, the fitness participant will backpedal past cone one to complete the test.

Additional Notes:

- Perform drill multiple times alternating the order the fitness participant goes left or right.
- Timing begins when the fitness participant starts moving and ends when they return to their starting position.

Agility Addition:

- Change directions in response to auditory or visual stimuli.
- Catch and throw a ball from the coach or partner.

Box Drill

Difficulty: low-medium

Exercise Instructions:

1. Start by creating the box grid out of 4 cones creating a square that is 5 yards long on each side.
2. Starting position can vary to adjust difficulty with the start and end drills.
3. The fitness participant will maintain their hips facing forward throughout the drill.
4. The participant starts at the front right cone.
5. At the start of the drill, the fitness participant will laterally shuffle to the front left cone.
6. Next, they will backpedal from the front left cone to the back left cone.
7. Then they will laterally shuffle from the back left to the back right cone.
8. Finally, they will sprint from the back right to the front right cone and come to a complete stop at their starting position ending the drill.

Additional Notes:

- Pump arms in rhythm with the feet.
- Perform as fast as possible.
- Timing begins when the fitness participant starts moving and ends when they backpedal passed to their starting position.
- A common variation includes sprinting the entire course requiring the fitness participant to go around each cone.

Agility Addition:

- Change directions in response to auditory or visual stimuli.
- Catch and throw a ball from the coach or partner.

LEFT Drill

Difficulty: medium-high

Exercise Instructions:

1. Start by placing 2 cones 10 yards apart.
2. Starting position is at the first cone in an athletic stance.
3. When the test starts the fitness participant will sprint to the far cone and backpedal back to the start.
4. Then the participant will turn sideways and shuffle to the far cone and back. They should face the same direction both ways so that both the right and left leg lead at some point.
5. Then the participant will carioca to the far cone and back making sure to face the same way both directions again.
6. Finally, the fitness participant will sprint to the far cone ending the test.

Additional Notes:

Timing begins when the fitness participant starts moving and ends when they run past the far cone.

Agility Addition:

- Change directions in response to auditory or visual stimuli.
- Catch and throw a ball from the coach or partner.

Z-Drill

Difficulty: high

Exercise Instructions:

1. Start by creating a square grid out of 4 cones that measures 5 yards on each side. Place a fifth cone in line with the left side of the square but 5 yards farther away.
2. Have the fitness participant start on the right side of the square.
3. At the start, the fitness participant will laterally shuffle from the back right to the back left cone going behind the back left cone.
4. After shuffling past the back left cone, the participant will change direction without turning around and they will laterally shuffle forward to the front right cone. Their right foot should be leading.
5. They will shuffle just past the front right cone then change direction and laterally shuffle to the front left cone.
6. After shuffling slightly passed the front left cone, sprint passed the fifth and final cone.

Additional Notes:

- Perform drill three times at one starting position then switch for another three repetitions.
- Timing begins when the fitness participant starts moving and ends when they sprint past the fifth cone.
- The fitness participant’s hips should face forward the entire drill.

Agility Addition:

- Change directions in response to auditory or visual stimuli.
- Catch and throw a ball from the coach or partner.

Summary

SAQ training has proven to be effective for many fitness populations and should be considered as a valuable tool for personal trainers coaching athletes and general fitness clients alike.

The benefits include increased speed, agility, quickness, strength, endurance, body awareness, and with a cumulative overall effect of improved injury prevention.

The exercises used for SAQ training offer much room for progression for clients of all levels and abilities.

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Chapter 21

Principles of Balance Training

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Introduction

Balance is a fundamental skill in daily activity necessary for the safe completion of any type of movement or activity pattern. Specifically, balance refers to the body's ability to maintain its center of gravity over its base of support during a given action. It relies upon a feedback network from the vestibular, visual, and somatosensory systems for ideal and smooth motor function.

Essentially, balance is the ability of the body to maintain its equilibrium.[4] Proper balance not only aids in injury prevention but is vital for a variety of specific athletic movements.[1]

Individuals from many different populations benefit from incorporating balance training. Fitness professionals must have a working knowledge of balance training programming and exercises to safely and effectively implement balance training into fitness programs when appropriate. They must know basic balance concepts, how to progress movements, and the correct technique for exercises.

Balance Training Concepts

Center of Gravity

Center of gravity is refers to the point at which the entire weight of a body is concentrated so that, if supported at this point, the body remains in equilibrium in any position.[2, 14]

Base of Support

The base of support is the region of ground surface that the body contacts.[3, 14]

The center of mass operates perpendicular to the base of support, enabling the body to remain balanced through static or dynamic postures.[3]

Limit of Stability

The limit of stability is the maximum distance the body can move while remaining balanced before having to change the base of support.[4]

Static Balance

The body's ability to maintain equilibrium without movement.[4]

Semi-dynamic Balance

Semi-dynamic balance refers to the ability to stay in the same spot with the addition of movement.[4]

Dynamic Balance

Includes the ability to balance through motion including adjustments made to voluntary movement and to maintain balance during disruption from an outside influence.[4]

Vestibular System

The vestibular system resides in the inner ear and relates information relating to acceleration and guidance continuously, providing movement and positioning feedback.[5]

This system provides vital information for rapid compensatory movements in response to external or internal forces being applied to the body.

Somatosensory System

The somatosensory system is a network of neurons that provides direct input to the central nervous system via muscle and connective tissue receptors. It is largely responsible for aiding both proprioception and kinesthesia for sensorimotor feedback, including connecting sensations of touch, pain, pressure, movement, and temperature from the tissues to the brain.[6, 7]

Visual System

The role of the visual system in relation to balance is in the detection of movement. Motion detected by the retina can be utilized to determine whether the movement is occurring from the individual or the environment.[8, 9]

The combination of the vestibular, somatosensory, and visual systems creates the necessary components for a fully functioning system of balance, allowing the individual to operate optimally at rest or in motion.[5, 6, 8]

Sensorimotor Function

The sensorimotor system functions to maintain joint stability and equilibrium throughout static and gait postures. It utilizes the processing information acquired through sensory, motor, and central integration feedback.[10]

Neuromuscular Control

Neuromuscular control is used to define the interaction between the neurological and musculoskeletal systems. As relating to balance, neuromuscular control is responsible for involuntary muscular contractions to control joint motion and maintenance of joint stability.[10]

Balance is a necessity for function in everyday life. Accomplishing tasks that involve displacement in the body while staying upright will involuntarily rely upon the systems that contribute to overall balance ability.[14]

Only through continuous and rapid feedback from the vestibular, visual, and somatosensory systems will the body maintain its center of gravity in dynamic or postural positions.[1]

Balance Training Concepts

Center of Gravity
The point at which the entire weight of a body is concentrated. If the body is supported at the center of gravity, it will remain standing.

Base of Support
The ground surface region that the body contacts that enables balance in static or dynamic postures.

Limit of Stability
The maximum distance a body can move and remain balanced without changing the base of support.

Static Balance
The ability to maintain equilibrium without movement.

Semi-Dynamic Balance
The ability to remain in one spot while adding movement above the base of support.

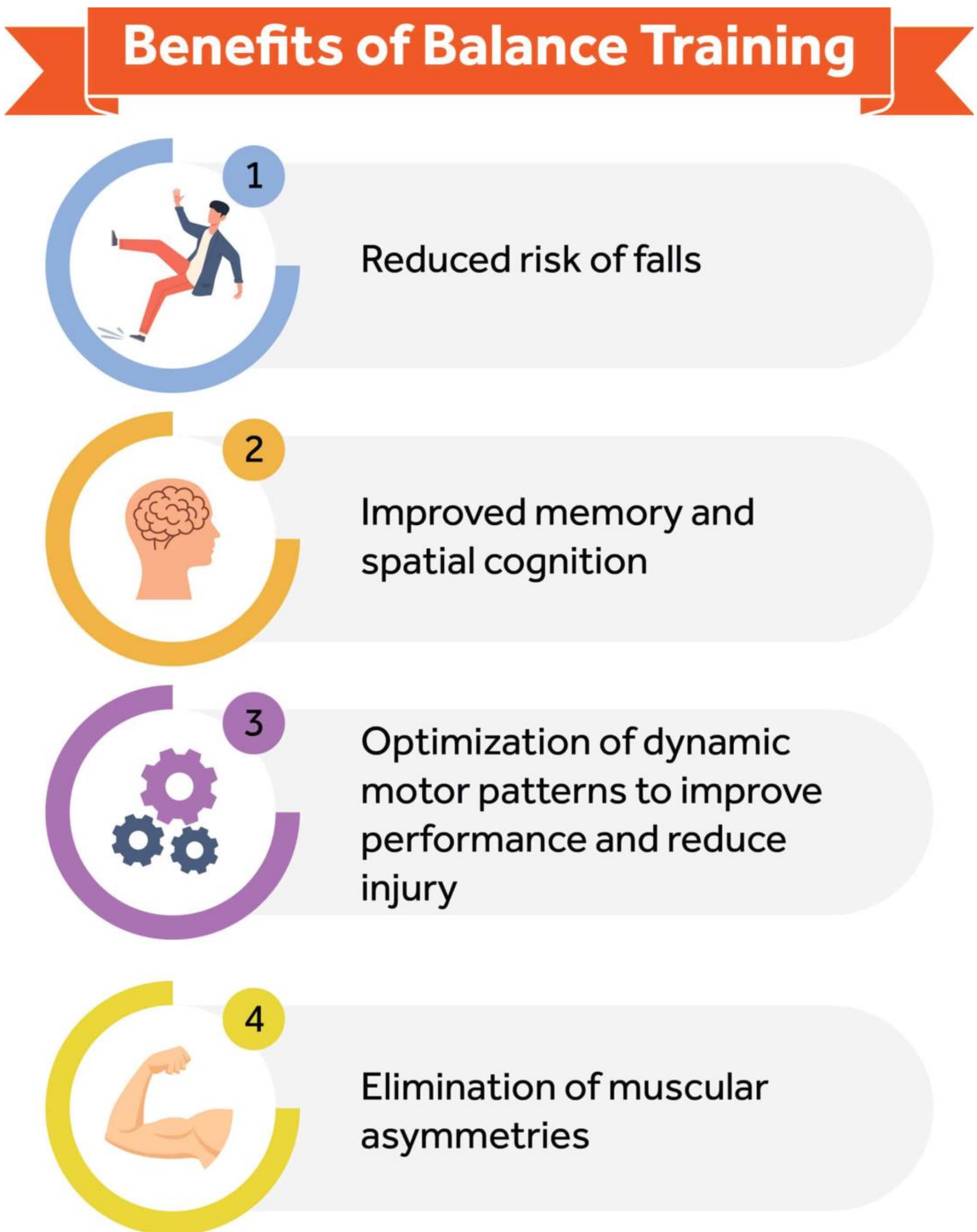
Dynamic Balance
The ability to balance through motion, including adjustments made to voluntary movement and external disruption.

Neuromuscular Control
Defines the interaction between neurological and musculoskeletal systems and is responsible for involuntary muscular contractions that control joint motion and maintain joint stability.

Benefits of Balance Training

Effective balance training carries a multitude of positive impacts for regular and athletic bodies alike. Positive effects directly related to balance training include:

1. Greatly reduced risk of bodily harm due to imbalance[1]
2. Improved memory and spatial cognition[11]
3. Optimization of dynamic motor patterns to improve performance and reduce injury [1,12]
4. Balance of muscular asymmetries[13]



Balance Training Progressions

Balance training requires a linear process that continually progresses from simple and safe exercises to more complex and unstable exercises as the body improves its sense of balance.[15]

Balance exercises occur in all three planes of motion.

Balance training seeks to introduce controlled instability as a client develops their sense of balance.[15]

From a movement plane perspective, exercises progress from sagittal, to frontal, and, finally, transverse.

Sagittal plane exercises have a high carryover to activities of daily life and thus have a high natural comfort level for users.

Frontal plane exercises introduce a combination of movements that will occur mostly in the frontal plane, but also have some interaction in the sagittal plane.

This added layer of complexity challenges the body and the balance by adding additional stress and dynamics with movement.[16]

Finally, the transverse plane utilizes a wide range of muscles with crossover to both the sagittal and frontal planes. The rotational nature of the exercises particularly challenges the visual balance system.

Creating exercise progressions uses a similar logical progression from comfortable and stable to challenging and unstable.

Lower-body progression

Two-legged stance:

1. Begin with a two-legged stance with feet shoulder width apart on a firm stable surface.
2. Move to narrow the stance, still on two feet and a stable surface.
3. Finally, progress to a staggered stance or heel-to-toe.

The initial positioning of the two-legged stance creates a wide base of support, making it easy for the user to maintain the center of gravity. With the first progression the base of support is narrowed reducing the area available to balance the center of gravity.

The progression to heel-to-toe maximally reduces the width of the base of support and will likely accompany postural sway as the user works to maintain their center of gravity.

After successfully completing heel-to-toe exercises, the next progression in balance training is to move to single-leg stance exercises.

One-legged stance, or unstable surface:

1. Begin with a single-leg stance on a solid surface.
2. Move to a two-legged stance on an unstable surface or balance modality.
3. Finally, progress to a single-leg stance on an unstable surface or balance modality.

The first progression to a single-leg stance greatly reduces the overall surface area of the base of support and reduces the number of points of contact with the ground. Reducing contact points also decreases the number of pressure and touch sensors communicating with the central nervous system.

Following a single-leg stance, the next progression brings users back to a two-legged stance but on an unstable surface. Having a floor or modality that is constantly changing challenges the user's perception of where they are in space, directly engaging the somatosensory system as proprioceptive feedback will rapidly change as the surface shifts. The next progression to single-leg stance again reduces the overall area of the base of support.

External force:

Up to this point all balance progressions utilized only the internal force of the user's own body. After passing single-leg and unstable surface exercises, the next progression incorporates an outside force upon the user.

1. Push or pull in one direction or movement plane.
2. Push or pull in multiple directions or movement planes.

The addition of external forces accompanying the movement challenges the vestibular system and its ability to counteract force to maintain a center of gravity.

The outside force starts small, for example catching a tennis ball.

Then, the intensity progresses via increased weight, such as using a medicine ball. Additionally, incorporating additional planes of movement as balancing skills increase will train the entire balance system.

Additional Variables

Beyond adjusting foot positioning and the stability of the surface the user is balancing on, a few more progressions exist to challenge the ability to balance.

1. Closing eyes during exercise. Eliminating the visual system puts greater emphasis on the rest of the balance system as a full layer of sensory feedback is removed.
2. Additional cognitive tasks. Performing small mental tasks such as basic math while attempting to balance further challenges the brain's capacity to sort through incoming sensory feedback.

Technique for Select Balance Training Exercises

Tandem Stance

Difficulty: low

Exercise Instructions:

1. Start standing next to a wall or chair for safety.
2. Line feet up, heel-to-toe, in a standing stance.
3. Ensure toes of both feet are pointing straight ahead.
4. Hold position for the desired time then switch feet.
5. If needed, place a chair they may hold on to on either side in the event of loss of balance.

Single-Leg Balance

Difficulty: low

Exercise Instructions:

1. Start standing in a comfortable neutral position. Hands can be on hips or floating.
2. Flex one hip pulling foot off the floor and thigh to 90 degrees of hip flexion. Shoulders and hips should remain neutral.
3. Hold for desired time. Ranges typically vary between 5-30 seconds.
4. Repeat on the opposite side.

Balance can be aided in this position by maintaining full extension of the standing leg.

Single-Leg Balance Reach

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position with feet hip width apart. Hands can be on hips or floating.
2. Lift one leg while keeping the leg straight and float it directly in front of the body a few inches off the ground while 'reaching' forward with the foot. Maintain all weight on the stance leg. Do not step down with the reaching foot
3. The exercise can be progressed by abducting the floating leg or opening the leg up into external rotation.
4. Repeat on the opposite side.

Single-Leg Hip Rotation

Difficulty: low

Exercise Instructions:

1. Start standing in a comfortable neutral position. Hands can be on hips or floating.
2. Flex one hip, pulling the foot off the floor and thigh to 90 degrees of hip flexion. Shoulders and hips should remain neutral.
3. Externally and internally rotate elevated leg at a controlled pace, holding briefly at the end range of motion.
4. Repeat on the opposite side.

Single-Leg Lift and Chop

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position while holding a medicine ball to one hip.
2. Lift the opposite leg so that the body balances on a single leg with the medicine ball to that side.
3. Hips should stay neutral while holding the floating leg is off the ground.
4. Cross the medicine ball from hip of planted leg to the opposite shoulder in a diagonal pattern with straight arms.
5. Return to the start position and repeat.
6. Repeat on the opposite side.

Single-Leg Arm and Leg Motion

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Lean forward while simultaneously reaching the floating leg behind them to full extension and opposite arm (arm of the planted leg) forward to full extension.
4. Adjust the range of motion based on the user's capability level.
5. Continue performing the pattern for time.
6. Repeat on the opposite side.

Single-Leg Windmill

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Lean torso forward to 45 degrees while pushing hips back loading weight into the gluteus muscles.
4. Extend both arms directly out to the sides.
5. While maintaining balance, rotate arms and torso slowly as far as possible in each direction.
6. Continue performing the pattern for time.
7. Repeat on the opposite side.

Single-Leg Throw and Catch

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position while holding a medicine ball with both hands.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Toss the ball to a partner or trainer then catch the return toss while maintaining balance and alignment.
4. Repeat for time or repetitions.
5. Repeat on the opposite side.
6. To progress the exercise, increase the distance, velocity, or placement of the throws.

Single-Leg Squat

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Squat down on the planted leg as if sitting into a chair.
4. Make sure knee stays in line with toes to avoid knee stress or injury.
5. Hold briefly at the bottom of the squat.
6. Fully extend the planted leg extending through the gluteal muscles to return to standing.
7. Repeat for time or repetitions.
8. Repeat on the opposite side.

Single-Leg Squat Touchdown

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Squat down on the planted leg as if sitting in a chair.
4. Make sure the knee stays in line with the toes to avoid knee stress or injury.
5. At the bottom of the squat, reach the opposite hand to touch the toes of the planted foot.
6. Fully extend the planted leg extending through the gluteal muscles to return to standing.
7. Repeat for time or repetitions.
8. Repeat on the opposite side.
9. If unable to reach the toes, adjust the target to the leg or knee and work back down to the toes over time.

Single-Leg Romanian Deadlift

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg off the floor into a single leg balance position with shoulders and hips staying neutral.
3. Keep the floating foot off the ground a few inches but next to the planted leg.
4. Hinge forward at the hip of the planted leg, the torso should lean forward while the tailbone drives backward.
5. Planted leg should remain extended with a minimal amount of knee bend.
6. Reach for the planted foot with the opposite hand trying to touch the toes of the planted foot.
7. Using the gluteal and abdominal muscles, extend the planted hip to return to an upright position.
8. Repeat for time or repetitions.
9. Repeat on the opposite side.

Multiplanar Step-Up to Balance

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position directly in front of a stable elevated surface like a box, platform, or step.
2. For the sagittal plane, lift one leg and place foot directly on top of the elevated surface.
3. Toes and knee of forward foot should be aligned.
4. Shift weight towards the forward foot pushing through the heel and extend the forward leg through the gluteal muscles and quadriceps to bring the body upright on top of the elevated surface.
5. Hold top position for balance with opposite leg flexed in front of body to 90 degrees at both the hip and knee.
6. Return lifted leg to the ground followed by the standing leg.
7. Repeat for time or repetitions.

Progressions include:

- Alternating legs every repetition.
- Incorporate the frontal plane by performing a lateral step-up sideways to the elevated surface. The lateral step-up focus will be on stacking the hips, knees, and ankles in one vertical column during the movement.
- Incorporate the transverse plane by performing a rotational step-up from the side of the elevated surface while rotating to face the surface while placing the stepping foot. The opening step to place foot on the elevated surface will involve rotating the body to mirror the traditional step-up. Between the opening and closing rotation from/to start position, the checkpoints will be the same as the regular step-up.

Multiplanar Lunge to Balance

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. For the sagittal plane, lift one foot off the ground and step forward into a lunge with knees and toes pointing forward.
3. Forward foot should be flat on the ground with forward knee directly above the ankle.
4. Back foot will be pivoted onto toes and shoulders should be above the back knee.
5. Both knees should bend to 90 degrees.
6. Drive through the forward foot to extend the forward leg and push the weight back to the back leg.
7. Come into a standing position on the back leg with the forward leg held in a balance position at 90 degrees of hip and knee flexion.
8. Repeat for time or repetitions.

Progressions include:

Incorporate the frontal plane by performing a lateral lunge to balance. The initial step will be to the side and focus on the forward leg will be on stacking the hips, knees, and ankles in one vertical column.

Incorporate the transverse plane by performing a rotational lunge. The initial step will rotate the hips externally, so the user's forward foot moves laterally and posteriorly to the back foot.

Multiplanar Hop with Stabilization

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position.
2. Lift one leg into a single leg balance stance.
3. To perform in the sagittal plane, hop forward off the balancing leg and land on the opposite leg in a single leg balance position.
4. Hold the balance position for 3-5 seconds.
5. Hop backwards returning to the start position and landing in single leg balance on the original leg.
6. Hold the balance position for 3-5 seconds.
7. Repeat for time or repetitions.

Progressions include:

Incorporate the frontal plane by performing a lateral hop to balance. The start position is identical, but the hop goes laterally instead of front to back.

Incorporate the transverse plane by performing a rotational hop to balance. The start position is identical, but with external rotation of the balancing leg. The initial hop will go laterally and posteriorly to the side of the elevated leg. The second hop will still return to the start position.

Multiplanar Single-Leg Box Hop-Up with Stabilization

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position directly in front of a stable elevated surface like a box, platform, or step.
2. Lift one leg into a single leg balance stance.
3. To perform in the sagittal plane, hop forward off the balancing leg and land on the same leg, on top of the surface, and in a single leg balance position.
4. Hold the balance position for 3-5 seconds.
5. Step backwards to return to the start position.
6. Repeat for time or repetitions.

Progressions include:

- Hoping off the box as ability level allows.
- Incorporate the frontal plane by performing a lateral hop-up by stepping sideways to the elevated surface with the balancing leg closest to the surface. The hop onto the elevated surface will be lateral.
- Incorporate the transverse plane by performing a rotational hop-up by starting at the side of the elevated surface. The hop onto the elevated surface will incorporate rotating the body to land in a position that mirrors the sagittal plane hop-up. Between the opening and closing rotation from/to start position, the checkpoints will be the same as the sagittal hop-up.

Multiplanar Single-Leg Box Hop-Down with Stabilization

Difficulty: low

Exercise Instructions:

1. Start standing in a neutral position on top of a stable elevated surface like a box, platform, or step.
2. Lift one leg into a single leg balance stance.
3. To perform in the sagittal plane, hop forward off the balancing leg and land on the same leg, on the floor, and in a single leg balance position.
4. Hold the balance position for 3-5 seconds.
5. Return to the start position.
6. Repeat for time or repetitions.

Progressions include:

- Incorporate the frontal plane by performing a lateral hop-down by hopping laterally instead of anteriorly.
- Incorporate the transverse plane by performing a rotational hop-up by hopping with an external rotation instead of moving anteriorly. The landing position should be a 90 degree turn from the start position.

Summary

Balance training progressions should systematically challenge the neuromuscular system to produce effective improvements. The overall safety of the user or client is a priority as their ability to balance improves, so as not to overwhelm the balance system creating vulnerability to injury. Progression should follow the format of:

1. Easy to hard
2. Simple to complex
3. Stable to unstable
4. Static to dynamic
5. Slow to fast
6. Eyes open to eyes closed
7. Known to unknown (cognitive task)

8. Single task to dual-task

Some commonly used pieces of balance equipment that are highly effective at challenging the neuromuscular system include:

1. Floor: utilizing a soft floor surface creates a minimal amount of instability forcing greater recruitment of balance training systems.
2. Balance beam: a narrow-elevated surface that reduces the base of support available to the user.
3. Half-foam roll: a semi-cylinder where the user stands on the curved surface. The flat surface is stable to avoid movement but standing on the arc of the roller greatly reduces points of contact and the base of support for the balancer.
4. Foam pad: dense pad typically between 1-3 inches thick that dramatically reduces the stiffness of the standing surface. User can be pushed into any direction due to the give of the foam pad.
5. Balance disc: small disc filled with air that provides greater give than the foam pad. Users can experience rapid changes in balance or direction.
6. Wobble board: solid board with an attached curvy surface. Typically, user stands on the flat surface with the curved surface in contact with the solid floor. The combination of materials makes for rapid changes in direction if weight compensations occur from the user.

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Chapter 22

Corrective Exercise

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Introduction

Corrective exercise involves an integrated approach to identifying muscle imbalances and creating an individualized program of flexibility, isolated strengthening, and functional movements to restore proper muscle balance, improve movement quality, and reduce injury risk in otherwise healthy clients.

Fitness professionals with an understanding of corrective exercise and its application can provide better service and results for clients with underlying muscular imbalances.

While there is some overlap between corrective exercise modalities and physical therapy modalities, corrective exercise is used by certified trainers to address movement and postural issues in clients without serious injuries.

Physical therapists utilize similar modalities to address specific injury issues in patients and rehabilitate them to normal day-to-day activity.

Fitness professionals must understand that while the approaches are similar in many cases, physical therapists have many years of advanced training, preparing them to deal with medical rehabilitation. Personal trainers are not qualified to treat medical injuries requiring physical therapy.

Diagnosing and treating injuries falls outside the scope of practice for a CPT, but developing individualized exercise programs that help someone move better is within the Trainer Academy CPT Scope of Practice.

Corrective exercise restores the proper function of the kinetic chain which may reduce injury risk and fatigue. The saying "straighten before you strengthen" emphasizes the importance of proper movement and the use of corrective exercises to achieve that goal.[1]

Corrective exercise focuses on improving the qualities of mobility, stability, and common movement patterns using modalities such as foam rolling, stretching, activation, and integration exercises. The purpose of corrective exercise is not to increase physiological parameters like aerobic and anaerobic power, but to restore muscle tone, muscle length, muscle tension, and freedom of movement.[2]

An appropriately designed corrective exercise program will help to improve stability, proprioception, timing, and motor control while addressing limitations and asymmetries in basic movement patterns.

To use corrective exercises effectively, the CPT will need an understanding of the proper modalities, when to use them, and how to sequence them in the correct order with progressions.

Corrective Exercise Rationale

Muscle imbalances caused by poor posture, repetitive movements, and prolonged periods of sitting create shortened and lengthened muscles, which causes weakness and tightness in those muscles.[1, 3, 5] This leads to faulty alignment of joints and alters the physiological and neurological properties of the muscle that results in movement compensation and dysfunction.[1, 2, 3]

Joint stability, the ability to maintain and control joint movement and position, and joint mobility, the range of motion (ROM) around a joint, are maintained by proper length-tension and force-couple relationships of muscles, proper arthrokinematics, proprioceptors, and mechanoreceptors.[2]

An optimal length-tension relationship is the length of the muscle where the greatest number of potential cross bridge sites occurs, allowing for optimal force production of the muscle.

Muscle imbalances alter this relationship and decrease the force output of the muscle.[1, 2, 3] Both the shortened muscle and lengthened muscles on opposite sides of the joint are outside of their optimal length-tension relationships and do not produce force effectively.

Muscles in a lengthened state can chronically activate muscle spindles. Muscle spindles, mechanoreceptors located in the muscle belly, detect the length and rate of stretch in the muscle. When muscle spindles detect an overstretching, they cause the antagonist muscle to contract to prevent damage. The tension from the antagonist contract discharge of GTOs (Golgi tendon organs) results in decreased force production.[1, 3]

Force couples from muscles provide opposing directional or contralateral pulls at joints.[1] These force couples maintain proper posture, and joint alignment, allowing for normal movement and distribution of forces to occur. Tight and weak muscles alter the force couples, causing changes in posture and arthrokinematics, resulting in compensatory movement and losses in stability and mobility.[1,2,3]

Altered force couples and length-tension relationships weaken the muscles on both sides of the joint. Corrective exercise modalities are an effective way to address muscle imbalances and restore mobility and stability to allow proper motion and mechanics.

Corrective exercise modalities must follow a systematic progression. Performing modalities that address mobility and stability before movement and performance is the best approach for long term success and injury prevention in clients with non-clinical movement dysfunctions.

Exercising without regard for mobility and stability may do more harm than good and does not adequately develop an exercise program based on the client's needs.[1]

Corrective Exercise Methods

Results from the client's movement assessments will dictate where to start.

Mobility and stability issues should be resolved before any movement is performed. Initially, the focus will be on correcting muscle imbalances to restore freedom of movement. Self-myofascial release (SMR) is used for loosening up tight shortened muscles and relaxing hypertonic muscles to restore ROM.[4]

Foam rolling targets tightened areas in muscles called trigger points, which can decrease ROM by decreasing the elasticity of the connective tissue.[3] Commonly performed with a foam roller, SMR works by stimulating GTOs, causing autogenic inhibition and relaxing the affected area.

Increases in blood flow help alleviate inflammation as well. SMR may be performed alone and some evidence suggests that it may improve ROM without the decreases in force production seen with static stretching.[1, 3, 4] SMR may be performed before and after exercise, but to enhance results it should be before any other type of stretching.[1,3,5]

Along with SMR, passive, active, and PNF stretching can help correct muscle imbalances, increase joint range of motion, decrease the excessive tension of muscles, relieve joint stress, improve the extensibility of the musculotendinous junction, maintain the normal functional length of all muscles, improve neuromuscular efficiency, and improve function.

Static stretching reduces the sensitivity of muscle spindles and lengthens connective tissue when the stretch force is applied.[1] Generally, the client performs a brisk aerobic warm-up to increase core temperature, then applies SMR to loosen up the muscle followed by static stretching.

Restoring ROM and addressing instability are the first concerns. While flexibility techniques are useful for alleviating shortened muscles, the antagonist is usually lengthened and underactive, which requires restoring the muscle's ability to produce force at its resting length. Activation exercises will address this issue by restoring endurance, strength, and proper recruitment patterns to the underactive muscle.

Restoring muscle imbalances using flexibility and activation exercises will restore the length-tension relationships and altered force-couples allowing for the required mobility and stability needed for functional movement to occur. From there, integration exercises can be used to restore dynamic balance and proper movement patterns.

To avoid training the muscle in its lengthened state, activation exercises initially involve isometric movements at joint-specific angles. Supportive devices like the wall, floor, or back of a chair can be used to provide kinesthetic awareness and allow the client to understand the alignment of the joints involved.[1]

To avoid training the muscle in the lengthened state, the exercise can be progressed to greater ranges of motion, progressing from static to dynamic movements. The goal of corrective flexibility is to restore the muscle's force production at normal and resting lengths, not to become flexible beyond normal requirements.

Once the lengthened and shortened muscles have been addressed and the client demonstrates the necessary mobility and stability in the area, the progression to dynamic movements happens though can incorporate integration exercises to work the body in a synchronous and coordinated fashion.[1]

After correcting muscle imbalances and restoring mobility and stability to an area, the athlete must retrain the poor compensatory motor patterns created previously. Integration exercises will restore and groove proper movement patterns.[1, 3, 4] These exercises incorporate multi joint movements and movements in multiple planes of motion.

A key concept when using the corrective exercise strategies and modalities is that "proximal stability promotes distal mobility." This concept states that for distal joints to be mobile, such as the hips and shoulders, proximal joints must be stable. Proximal stability revolves primarily around stabilizing the core and spine. If these areas are unstable, risk of injury goes up and distal joints and muscles may increase tightness to prevent injury as a response to the instability in the core.

A properly strengthened, stable core is key for improving mobility in the commonly-restricted areas of the human body.

This is an example of a proper corrective exercise progression:

1. Stabilize the lumbar spine
2. Restore mobility to the hips and thoracic spine
3. Stabilization of the shoulder girdle and glenohumeral joint[1]

Corrective exercise is an important component of any CPT's training acumen. Often trainers come across common movement dysfunctions such as a client with pronation syndrome due to tight hip adductors or weak hip external rotators causing knee valgus.

They might have lower crossed syndrome, causing an anterior pelvic tilt due to tight hip flexors and weak extensors, adding to the excessive lumbar lordosis.

The client might have upper cross syndrome from tight pectoralis muscles and weak middle and lower trapezius, thus creating rounded shoulders and a kyphotic thoracic spine.[3]

These common syndromes will inhibit clients from moving safely and effectively, which will compromise the results of their exercise program while increasing their risk of injury.

CPTs not only need to be able to identify and correct the muscle imbalances associated with these syndromes, but they should correct the faulty motor patterns to restore proper movement. Knowledge of the corrective exercise modalities and when to use them is an integral part of the CPT's training toolbox.

Corrective Approaches Based on Movement Assessments

Overhead squat, single leg squat, and lunge/step over assessments

Knee Valgus

Suspected Tight Muscles:

- Hip adductors, tensor fascia latae (TFL), gastrocnemius, soleus, IT band, short head of biceps femoris

Suspected Weak Muscles

- Gluteus maximus, gluteus minimus, anterior and posterior tibialis

Self Myofascial Release (SMR)

- Gastrocnemius, soleus, adductors, TFL, IT band, short head of biceps femoris
- Hold each area for a minimum of 30 seconds

Static stretch

- Gastrocnemius, soleus, adductors, adductors, TFL, biceps femoris
- 30 second hold or 7-10 second isometric contraction and 30 second hold

Isolated Strengthening

- Gluteus maximus, gluteus medius, anterior tibialis, posterior tibialis
- 10–15 repetitions for each exercise with 2-second isometric hold and 4-second eccentric contraction

Functional Exercises

- Ball squats, step-ups, lunges, single leg squats
- 10-15 repetitions as an integrated exercise

Pronation

Suspected Tight Muscles

- Gastrocnemius, soleus, peroneals, short head of biceps femoris

Suspected Weak Muscles

- Tibialis group, medial hamstrings

Self Myofascial Release (SMR)

- Lateral gastrocnemius, peroneals, short head of biceps femoris
- Hold each area for a minimum of 30 seconds

Static Stretch

- Gastrocnemius, soleus, short head of biceps femoris
- 30 second hold or 7-10 second isometric contraction and 30 second hold

Isolated Strengthening

- Posterior tibialis, anterior tibialis, hamstrings

Functional Exercises

- Step up to balance, and single leg balance reach for 10-15 repetitions as integrative exercise[5]

Arms Falling Forward

Suspected Tight Muscles

- Latissimus dorsi, pectoralis, and thoracic spine (T-Spine)

Isolated Strengthening

- Middle and lower trapezius, and rotator cuff

Self Myofascial Release (SMR)

- Latissimus dorsi and thoracic spine
- Hold each area for a minimum of 30 seconds

Static Stretch

- Latissimus dorsi and pectoralis major
- Hold for at least 30 seconds

Isolated Strengthening

- Rotator cuff, middle and lower trapezius

Functional Exercises

- Squat to row, 10-15 repetitions

Excessive Forward Lean

Suspected Tight Muscles

- Psoas/iliacus, gastrocnemius, and soleus

Suspected Weak Muscles

- Gluteus maximus, anterior tibialis, erector spinae, and core stabilizers

Self Myofascial Release (SMR)

- Gastrocnemius, soleus, and hip flexors
- Hold each area for a minimum of 30 seconds

Static Stretch

- Gastrocnemius, soleus, abdominals, and hip flexors
- 30 second hold or 7-10 second isometric contraction followed by a 30 second hold

Isolated Strengthening

- Anterior tibialis, gluteus maximus, erector spinae, and core stabilizers

Functional Exercises

Ball wall squat with overhead press 10-15 repetitions

Excessive Lower Back Arch

Suspected Tight Muscles

- Psoas major and minor, iliacus, erector spinae, and latissimus dorsi

Suspected Weak Muscles

- Gluteus maximus and abdominals

Self Myofascial Release (SMR)

- Hip flexor complex and lats
- Hold each area for a minimum of 30 seconds

Static Stretch

- Hip flexor complex, lats, and erector spinae
- 30 second hold

Isolated Strengthening

- Gluteus maximus and abdominals

Functional Exercises

- Ball wall squat with overhead press

Asymmetrical Weight Shift

Suspected Tight Muscles

- Adductors, TFL, IT band on same side and piriformis, biceps femoris, gastrocnemius, and soleus on opposite side

Suspected Weak Muscles

- Gluteus medius same side, and adductors opposite side

Self Myofascial Release (SMR)

- Adductors, TFL, and IT band on the same side, and piriformis, biceps femoris, gastrocnemius, and soleus on the opposite side
- Hold each area for a minimum of 30 seconds

Static Stretch

- Adductors, TFL on the same side, and piriformis, gastrocnemius, soleus, and biceps femoris on the opposite side

Isolated Strengthening

- Gluteus medius (same side) and adductors (opposite side)

Functional Exercises

- Ball wall squat with overhead press

Excessive Lower Back Rounding

Suspected Tight Muscles

- Hamstrings and adductor magnus

Suspected Weak Muscles

- Gluteus maximus, hip flexors, and erector spinae

Self Myofascial Release (SMR)

- Hamstrings and adductor magnus
- Hold each area for a minimum of 30 seconds

Static Stretch

- Hamstrings and adductor magnus

Isolated Strengthening

- Gluteus maximus, hip flexors, and erector spinae

Functional Exercises

- Ball wall squat with overhead press

Forward Head

Suspected Tight Muscles

- Thoracic spine, sternocleidomastoid, levator scapulae, and upper trapezius

Suspected Weak Muscles

- Deep cervical flexors, cervical erector spinae, and lower trapezius

Self Myofascial Release (SMR)

- Thoracic spine, sternocleidomastoid, levator scapulae, and upper trapezius
- Hold each area for a minimum of 30 seconds

Static Stretch

- Sternocleidomastoid, levator scapulae, and upper trapezius
- 30 second hold

Isolated Strengthening

- Cervical flexors, cervical erector spinae, and lower trapezius
- 10-15 repetitions with a 2 second isometric hold and a 4 second eccentric contraction

Functional Exercises

- Ball combo with cervical retraction for 10-15 repetitions

Push & Pull Assessments

Forward Head

Suspected Tight Muscles

- Thoracic spine, sternocleidomastoid, levator scapulae, and upper trapezius

Suspected Weak Muscles

- Deep cervical flexors, cervical erector spinae, and lower trapezius

Self Myofascial Release (SMR)

- Thoracic spine, sternocleidomastoid, levator scapulae, and upper trapezius
- Hold each area for a minimum of 30 seconds

Static Stretch

- Sternocleidomastoid, levator scapulae, and upper trapezius
- 30 second hold

Isolated Strengthening

- Cervical flexors, cervical erector spinae, and lower trapezius
- 10-15 repetitions with a 2 second isometric hold and a 4 second eccentric contraction

Functional Exercises

- Ball combo with cervical retraction for 10-15 repetitions

Excessive Lower Back Arch

Suspected Tight Muscles

- Psoas major and minor, iliacus, erector spinae, and latissimus dorsi

Suspected Weak Muscles

- Gluteus maximus and abdominals

Self-Myofascial Release (SMR)

- Hip flexor complex and lats
- Hold each area for a minimum of 30 seconds

Static Stretch

- Hip flexor complex, lats, and erector spinae
- 30 second hold

Isolated Strengthening

- Gluteus maximus and abdominals

Functional Exercises

- Ball wall squat with overhead press

Scapular Winging

Suspected Tight Muscles

- Latissimus dorsi, pectorals, serratus anterior, T-spine

Suspected Weak Muscles

- Middle and lower trapezius

Self-Myofascial Release (SMR)

- Latissimus dorsi and T-spine
- Hold each area for a minimum of 30 seconds

Static Stretch

- Lats, pecs, and serratus anterior
- 30 second holds

Isolated Strengthening

- Middle and lower trapezius

Functional Exercises

- Standing 1-arm cable chest press for 10-15 repetitions

Scapular Elevation

Suspected Tight Muscles

- Upper trapezius, levator scapulae, and pectoral muscles

Suspected Weak Muscles

- Middle and lower trapezius

Self Myofascial Release (SMR)

- Latissimus dorsi and T-spine
- Hold each area for a minimum of 30 seconds

Static Stretch

- Lats, pecs, and serratus anterior
- 30 second hold

Isolated Strengthening

- Middle and lower trapezius

Functional Exercises

- Single leg Romanian deadlift with PNF pattern for 10-15 repetitions

Technique Descriptions for Select Exercises

SMR techniques

Calves

1. Begin in a seated position with legs straight.
2. Place foam roller under calf.
3. Position non-SMR leg on top of the SMR leg to increase pressure.
4. Roll calf area upwards from the ankle until you find a tender spot.
5. Hold tender spot for 30 seconds.

TFL/IT band

1. Begin lying on one side, the foam roller just in front of the hip.
2. Cross the top leg over lower leg, with foot touching the floor.
3. Slowly roll from hip joint towards the knee until you find a tender spot.
4. Hold tender spot for 30 seconds.

Piriformis

1. Begin seated on the foam roller.
2. Cross one ankle over the opposite thigh.
3. Put weight into the hip of the crossed leg.
4. Slowly roll on the posterior hip until you find a tender spot.
5. Hold tender spot for 30 seconds.

Latissimus Dorsi

1. Begin lying on one side.
2. Extend the ground side arm with thumb facing upward.
3. Place the foam roller under the armpit, perpendicular to the lat.
4. Roll across area until you find a tender spot.
5. Hold tender spot for 30 seconds.

Static Stretching Techniques

Perform 1-3 sets and hold for a minimum of 30 seconds.

Gastrocnemius

1. Begin standing facing a wall or rack.
2. Step one leg back, maintain a straight knee and hip and ensure heel remains on floor.
3. Lean toward the wall by bending arms, engage glutes and quadriceps while keeping heels on the floor.
4. Hold for 30 seconds.

Tensor Fasciae Latae

1. Begin in a staggered stance, keep slight bend in front knee and back leg straight.
2. Squeeze gluteal muscles while rotating pelvis posteriorly.
3. Slowly move body forward until you feel the stretch in the front of the rear hip.
4. To increase the stretch, raise the arm up and over to the opposite side while maintaining pelvis position.
5. Hold for 30 seconds.
6. Repeat on both sides.

Hip Flexor

1. Begin kneeling with front and legs bent to 90 degrees.
2. Rotate pelvis posteriorly and squeeze gluteal muscles of the back leg.
3. Move body forward you feel a stretch in the front of the back hip.
4. To increase intensity, raise arm and bend to the opposite side.
5. Hold for 30 seconds.

Adductor

1. Begin standing with legs in a straddled stance, keep feet shoulder-width apart or further depending on flexibility.
2. Engage core and rotate pelvis posteriorly
3. Move hips sideways by bending at the right leg and shifting to the right, keeping the left leg straight.
4. Move sidewards until a stretch is felt in the inner thigh of the left leg.
5. Hold for 30 seconds.

Latissimus dorsi

1. Begin kneeling in front of a stability ball.
2. Extend both arms in front of you with thumbs upward, keeping a slight bend in the elbow, and place the blades of your hand on the ball.
3. Engage core, rotate pelvis posteriorly, and gently round through the back.
4. Slowly extend arms until a stretch is felt in the lat area under each armpit.
5. Hold for 30 seconds.

   Note: this stretch can be performed one arm at a time or both at the same time.

Pectoralis

1. Stand next to a tall object that will allow you enough room to place your forearm vertically against the object with elbow and shoulder joints each bent to 90 degrees.
2. With forearm in position, engage core and slowly lean forward until a stretch is felt in the anterior shoulder and chest region.
3. Hold the stretch for 30 seconds.
4. Repeat on both sides.

Upper Trapezius/Scalenes

1. Begin standing with an upright posture.
2. Engage core to prevent torso movement.
3. Retract and depress the scapula on the left side to target the left upper trapezius and scalenes.
4. Slowly tuck chin and laterally flex the neck, by bringing your ear to your right shoulder, until a stretch is felt in the left neck and trapezius.
5. Hold the stretch position for 30 seconds.
6. Repeat on the opposite side.

Strengthening Exercises

Perform 1-3 sets of 10-15 repetitions for all exercises

Prisoner Squat

1. Begin standing with upright posture and place hands behind the head with shoulders abducted and flexed to 90 degrees.
2. Engage core and lower into a squat by extending hips backwards and while lowering.
3. When you reach the target depth, extend through the hips, knees, and ankles to return to the top position.
4. Repeat for all repetitions.

Note: proper squat mechanics including knees tracking toes, no excessive lean, arched back, or other compensations should be permitted.

Multiplanar 3-Way Lunge with Reach

1. Begin standing with an upright posture.
2. Engage core and step forward (sagittal plane), and descend into a lunge position while reaching forward.
3. Use hip and thigh muscles to push up and back to the start position.
4. For the next repetition, perform a side lunge by stepping laterally with the working leg, bending the knee, and lowering into the side lunge.
5. Push away and down with the working foot to return to the starting position.
6. For the next repetition, step laterally with the left foot while rotating the foot, leg, and knee 90 degrees so your are now facing left instead of forward.
7. Drive through the floor and return to the start position.
8. Repeat the 3-way lunge flow for the target number of repetitions.

Step Up to Balance

1. Begin standing with an upright posture and a step or box in front of you. To add resistance, hold a dumbbell in each hand.
2. Step onto the box with one leg, keep foot pointed forward and knee tracking with the toes.
3. Push through the step-up foot to stand straight.
4. Bring the non-step up foot up by flexing 90 degrees at both the hip and knee.
5. At the top, balance for 1-2 seconds with the non-stepping ‘floating’ leg elevated in the 90-90 position.
6. Step back to the floor with the floating leg and return to the start position.
7. Repeat on both sides for target repetitions.

Single Leg Touchdown Squat

1. Begin standing with an upright posture and elevate one foot about 4 inches above the ground by flexing at the knee and hip.
2. Bend the ankle, knee, and hip of the standing to perform the single leg squat while reaching the opposite hand toward the planted foot.
3. Repeat on both sides for the target repetitions.

Tube Walking Side-Side

1. Begin standing with an upright posture.
2. Place resistance tubing around legs either just above or below the knee (easier) or at the ankle (harder).
3. Step laterally against the band resistance. Keep feet pointing forward with a slight bend in the knee and maintain an athletic position.
4. Step with the trailing foot to complete the repetition movement.
5. Perform lateral walks in both directions for the target repetitions.

Medicine Ball Lift and Chop

1. Begin standing with an upright posture with knees slightly bent and feet pointing forward.
2. Grab a medicine ball with both hands and extend forward until elbows are fully extended.
3. With straight arms, lower the medicine ball diagonally towards the floor as you rotate through the torso.
4. Reverse the diagonal movement, bringing the medicine ball up towards the opposite shoulder.
5. Perform target repetitions for both sides.

Marching

1. Begin supine with knees bent at 90 degrees and hips bent at 45 degrees, feet flat with toes pointing forward, and keep arms by sides.
2. Slowly lift one foot off the floor by flexing at the hip while keeping knees bent at 90 degrees.
3. Raise the knee as high as possible while maintaining control.
4. Pause at the top position and slowly return to the starting position.
5. Repeat on each side for the target repetitions

2-legged floor bridge

1. Begin supine with knees bent at 90 degrees and hips bent at 45 degrees, feet flat with toes pointing forward, keep arms by sides.
2. Drive through both feet while engaging glutes until the hip crease is roughly straight.
3. Slowly lower pelvis to the floor to return to the starting position.
4. Repeat for target repetitions.

Prone Cobra

1. Begin on the floor in a prone position with arms and legs extended.
2. Engage gluteal muscles and pinch shoulder blades together.
3. Lift chest and arms off the floor keeping thumbs pointing up.
4. Thighs, knees, feet, chest, arms, and head should all be off the floor during engagement.
5. Hold the position for 1 to 2 seconds, then slowly lower to the start position.
6. Repeat for the target repetitions.

Plank

1. Begin on the floor in a prone position with forearms on the ground and feet together, elbows directly under shoulders.
2. Lift body off the ground by engaging core and glutes while supporting body weight through the forearms and feet. Keep chin tucked and back flat or neutral throughout.
3. Hold for target time and repeat for target repetitions.

Ball Crunch

1. Begin supine with stability ball under the low back, bend knees to a 90 degree angle.
2. Crunch upper body forward by flexing the abdominals and raising the chest and neck.
3. Slowly return to the start position.
4. Repeat for the target repetitions.

Cable Rotation

1. Begin standing facing a cable machine, grasping handle with straight arms. Keep an upright posture and knees slightly flexed. The angle of pull should be opposite the direction of the target direction.
2. Keeping arms straight, rotate torso against the angle of pull until facing the opposite direction.
3. Return to the start position.
4. Repeat for the target repetitions.

Single Leg Romanian Deadlift

1. Begin standing with an upright posture with feet shoulder-width apart and knee slightly flexed.
2. Lift the non-working leg off of the floor roughly 4 inches.
3. Keeping a neutral spine, bend forward at the hip while kicking the floating leg backward and reaching towards the planted foot with the opposite hand.

Incorporating Corrective Exercise into Standard Programs

Once the client is able to perform movement screenings without major dysfunction, they may begin to transition to a regular fitness program. However, corrective exercise techniques can be incorporated

Tight overactive areas can be addressed with SMR and other stretching techniques during the warmup and cooldown.

Exercises that target the stabilizers of the shoulder can be used as warmups for upper body exercise and exercises that target the hip and abdominal stabilizers can be used to warm up lower body muscles.

Dynamic stretches that mimic the conditioning exercises can be used to warm up as well. Corrective exercise can be used as a form of active recovery, or the exercises can be grouped together as a circuit on their own.

Overall, corrective exercise can be used in the warmup, cool down, and in the main conditioning component of the workout once the client can safely and competently perform functional exercises.

Summary

Corrective exercise refers to a combination of techniques and approaches used to address postural and muscular imbalances in otherwise healthy clients. Fitness professionals benefit from knowledge of corrective exercise because it allows them to more effectively bring conditioned clients into a state of exercising regularly without injury, leading to better health outcomes.

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Chapter 23

Special Populations Considerations

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Introduction

In the context of personal training, special populations refers to any given subset of the general population that have special considerations when it comes to program design or exercise technique.

While many training principles apply across most populations, there are modifications and considerations that fitness professionals must make when working with various special populations.

An understanding of these modifications and when to apply them for certain types of clients greatly improves the fitness professional's ability to successfully deliver fitness results and prevent injury.

The main type of special populations client's fitness professionals must be familiar with are:

- Youth clients
- Older adult clients
- Pregnant clients
- Clients with chronic illnesses

There is always an additional risk factor in training special population clients. For clients with health conditions, medical clearance should always be obtained ahead of time.

Training Guidelines for Youth

Youth physical exercise typically comes from a combination of structured and unstructured activities. Considering youth are typically active in school periods or while playing sports, their ability to perform exercises over a longer period may be lower than that of a structured adult, due to overall fatigue.[1]

When developing a fitness program, individual programming should be considered for each child as abilities will be vastly different, regardless of similarities in age. Incorporating age-appropriate sports helps to increase aerobic function. Exercising develops muscle and bone strength in youth populations.[2, 3]

Physiological Differences Between Children and Adults

Fitness professionals who train children must understand the physiological differences between various age ranges and their implications for safely exercising. Children intake more oxygen per pound of body weight. They also have thinner skin, so dehydration and fluid loss is more prevalent.[4]

It is vital to ensure children stay well-hydrated, especially when exercising heavily or in a hotter environment. Though children do respond well to exercise, their bodies adapt somewhat differently to exercise than adults.[5, 6]

Youth Flexibility

Flexibility is the ability to move joints through a full range of motion.[8] Dynamic stretches help joints, and muscles move through their full range of motion. Assuming the child is otherwise healthy and mature enough to follow instructions, youth flexibility guidelines can follow adult flexibility guidelines.

Frequency

- Before and after each activity or exercise session (**or** 3 days per week)

Mode

- Static stretches for major muscle groups

Duration

- Hold stretch 10-15 seconds, two times per stretch

Intensity

- Mild tension or slight muscular discomfort

Special Considerations

- There are no special considerations unless the child has preexisting musculoskeletal conditions

Youth Resistance Training

Based on the latest research, youth resistance training for health and fitness conditioning shows a lower risk of injury when compared to playing traditional sports.[8] The most common injuries associated with resistance training are strains and sprains, which are largely attributable to poor technique coaching or lack of adult supervision during the session.

Strength training in prepubescent youths improves muscular endurance and strength, improves motor skills, protects against injury, has positive psychological effects, and provides a platform for safe and proper training.[9]

Frequency

- 2-3 times per week

Mode

- Use of bodyweight for major muscle groups

Intensity

- Very light to begin <40% of maximum effort

Duration

- 1 or 2 sets of 6-12 repetitions

Special Considerations

- Main objective is to introduce resistance training and correct movement patterns before applying more weight

Movement Assessment

- Overhead squat, push, pull, single leg balance, single leg squat

Youth Aerobic Training

To create an appropriate aerobic training program for children, trainers must consider the maturity of the child, medical status, and their previous experience with exercise.

Regardless of age, the exercise intensity should start low and progress slowly. Children should be physically active every day to create positive habits, expend energy, and develop healthy physical habits.[8] Provided proper technique guidelines are followed, children can safely perform most forms of aerobic exercise.

Frequency

- 3 times per week

Mode

- Walking/jogging, dancing, recreational biking and swimming

Intensity

Options:

- HR 50%-60% HRmax
- Moderate (beginning to sweat)

- RPE Borg 4- 5

Duration

- 30 minutes

Special Considerations

- Make activity fun, part of an active lifestyle

Programming Guidelines for Youth

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session (or 3 days per week)	2-3 times per week	3 times per week
Mode	Static stretches for major muscle groups	Use of bodyweight for major muscle groups	Walking / jogging, dancing, recreational biking and swimming
Volume	Hold stretch 10-15 seconds, two times per stretch	1 or 2 sets of 6-12 repetitions	30 minutes
Intensity	Mild tension or slight muscular discomfort	Very light to begin <40% of maximum effort	HR 50-60% HR max / Moderate / RPE Borg 4-5

Training Guidelines for Senior & Older Adult Populations

Current estimates indicate there are over 35 million Americans aged 65 and above.[10] Many older adults do not achieve the recommended amount of daily physical activity. Lack of exercise leads to lower metabolism, a weaker immune system, and chronic diseases.

Typical chronic diseases that develop are heart disease, stroke, diabetes, lung disease, Alzheimer's, hypertension, and certain cancers.[11, 12] A main component of aging is frailty with reduced physical function. Loss of muscular strength can lead to loss of independent living and an increased risk of developing various chronic diseases. Older adult populations are at a higher risk of developing osteoporosis, arthritis, low back pain, and obesity.[12]

Trainers must consider different risks that may require medical clearance and perform movement assessments to determine any muscle imbalances when designing exercise programs for seniors.

Some normal physiological adaptations that older adult populations experience are a decline in maximal attainable heart rate, cardiac output, muscle mass, balance, coordination, connective tissue elasticity, and bone mineral density.[13]

Aging fundamentally predisposes people to multiple morbidities that compound upon each other, often to the detriment of function and well-being.

For example, loss of skeletal muscle mass and bone mass accelerates in older populations which leads to less strength and a subsequent risk increase for falls and fractures.[15]

Hypertension is common in older populations because aging typically stiffens the arterial walls, due to the degeneration of elastic fibers and deposition of collagen and calcium in the walls of the arteries.[16]

This arterial stiffening raises the systolic blood pressure. Thus, isolated hypertension is commonly found in the elderly and constitutes a major risk factor. A healthy individual should have a blood pressure read of 120/80 mmHg and any individual, regardless of age, should be referred to their physician if their blood pressure reading is 140/90 mm Hg or higher.

Aside from the normal decline in physiological health, healthy older adults adapt to exercise the way normal, healthy adults would.[13] Encouraging older adults to exercise and demonstrating proper technique will help build their confidence to participate in resistance training and mobility exercises.

Before initiating any physical training, older adults must complete a Physical Activity Readiness Questionnaire (PAR-Q) and age-appropriate movement assessment to determine their capabilities before initiating an exercise prescription.

A flexibility assessment should be conducted with the movement assessment because older adults lose the elasticity of their connective tissue, which reduces range of motion and increases the risk of injury.

Older Adult Flexibility

Frequency

- Minimal two times per week

Mode

- Static Stretching

Duration

- 5-30 minutes total with 2 30-second bouts for each muscle group

Intensity

- Moderate intensity (5-6 on 0-10 scale)

Special Considerations

- Avoid ballistic movements and the Valsalva maneuver during the stretching routine.

Older Adults Aerobic Training

Frequency

- Moderate intensity exercises 5 times per week, or vigorous intensity 3 times per week

Mode

- Walking, cycling, seated recumbent, pool activity, and seated aerobics

Duration

- Moderate intensity exercise for 30-60 minute intervals; targeting 150-300min per week

Intensity

- Moderate intensity at 50%-70% HRR or 5-6 on the 10 point exertion scale

Special Considerations

- Muscle strengthening exercises and/or balance training may need to precede aerobic training among frail older adults.
- Comorbidities such as arthritis, osteoporosis, and heart disease need to be considered.
- Highly deconditioned adults with limited functional abilities should start with a low intensity and duration of physical activity.

Older Adult Resistance Training

Frequency

- Two or more times per week

Mode

- Resistance bands and free weights if multi station machines are not available

Duration

- 8-12 repetitions for each muscle group

Intensity

- 5-6 (moderate) or 7-8 (vigorous) on a 10-point scale

Special Considerations

- Strength training regimens depend on maximum resistance as well as endurance; supervision and cueing is helpful.
- Proper breathing is important- avoid the Valsalva maneuver for safety.
- Focus on building major muscle groups before challenging balance.

Movement Assessment

- Push, pull, OVH Squat (if possible) or sit to stand in a chair for balance

Programming Guidelines for Older Adults

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session (or 3 days per week)	Two or more times per week	Moderate intensity exercises 5 times per week, or vigorous intensity 3 times per week
Mode	Static stretches for major muscle groups	Resistance bands and free weights if multi station machines are not available	Walking, cycling, seated recumbent, pool activity, and seated aerobics
Volume	Hold stretch 10-15 seconds, two times per stretch	1-3 sets of 8-12 repetitions for each muscle group	Moderate intensity exercise for 30-60 minute intervals; targeting 150-300min per week
Intensity	Mild tension or slight muscular discomfort	5-6 (moderate) or 7-8 (vigorous) on a 10 point scale	Moderate intensity at 50%-70% HRR or 5-6 on the 10 point exertion scale

Training Considerations for Pregnancy

Collaborating with pregnant women to set appropriate and attainable goals will help them focus on efficacy, efficiency, and achieving success. Similar to a PAR-Q, having prenatal clients fill out a ParMed-X screening for pregnant women will help determine their level of readiness for an exercise program.[17]

Guidelines for Training Pregnant Clients

- If they already have an exercise prescription, continue this during the first trimester or minimum 30-40 minutes per day.
- With little or no previous exercise prescription, begin with 15 minutes of continuous exercise and slowly increase the duration to 30 minutes.
- During the second and third trimesters, vigorous exercise should be lowered.
- Avoid bouncing while stretching, exercises with risk of falling, sit ups, leg lowering exercises, and exercises performed in the prone position.
- Focus on hydration.
- Extend warm up and cool downs.

Contraindications to Training Pregnant Women

Some indications may be considered normal so please discuss first with the client. If new to exercise, pregnant women should be cleared for activity by their physician. These are a few contraindications to training pregnant women:

- Vaginal bleeding
- Dizziness
- Shortness of Breath
- Chest Pain
- Imbalance
- Swelling in outer limbs
- Painful contractions
- Amniotic fluid leakage

Aerobic Recommendations for Pregnant Women

Frequency

- 3-5 days per week

Mode

- Various weight bearing and non-weight bearing activities

Duration

- Work up to 30 minutes per day

Intensity

- Moderate or vigorous intensity for previously active women

Resistance Training During Pregnancy

Frequency

- 2-3 days per week

Mode

- Free weight machines and body weight exercises

Duration

- 1-3 sets for major muscle groups

Intensity

- Exercise to moderate fatigue with sub-maximal repetitions

Flexibility Training During Pregnancy

Frequency

- At least 2-3 days per week

Mode

- Targeting each muscle and tendon using active, passive, and dynamic forms of stretching

Duration

- 10-30 second holds

Intensity

- Stretch to the point of slight discomfort

Programming Guidelines for Pregnant Women

	Flexibility	Resistance Training	Aerobic Training
Frequency	At least 2-3 days per week	2-3 days per week	3-5 days per week
Mode	Targeting each muscle and tendon using active, passive, and dynamic forms of stretching	Free weights, machines, and body weight exercises	Free weights, machines, and body weight exercises
Volume	10-30 second holds	1-3 sets of 8-12 repetitions for each muscle group	Work up to 30 minutes per day
Intensity	Stretch to the point of slight discomfort	Exercise to moderate fatigue with sub-maximal repetitions	Moderate or vigorous intensity for previously active women
			Extend warm up and cool downs

Training Guidelines for Obesity

The World Health Organization defines overweight and obese as abnormal or excessive fat accumulation that may impair health.[19] Obesity is a rapidly growing issue in America where 1 out of 3 adults (68%) is overweight and over 31% of the population is obese.

The Task Force on Proposal for Public Actions states that obesity is largely a result of lifestyle. Short-term intervention has limited effectiveness, while long-term success is rare without an ongoing care plan or weight loss surgery.[18, 19]

Though weight loss surgeries can be successful in removing large amounts of fat, the person can gain it back if they do not commit to a fitness regimen and adequate nutrition planning.

In total, diet, lifestyle change, and exercise are essential components of obesity management.[19]

Body Mass Index

The common way to determine if a person is overweight or obese is to use body mass index (BMI). BMI is recommended by the National Institutes of Health to classify overweight and obesity and to estimate the relative risk of associated diseases.

Though this tool is widely used, it is important to note that BMI does not discriminate between fat mass and lean tissue. BMI does, however, significantly correlate with total body fat.[20] Body mass index is calculated as weight in kilograms divided by height in meters squared.

There are other tools to measure accurate body fat such as skin fold calipers, but this can become an uncomfortable situation with overweight clients and often trainers who use calipers need to practice under someone more experienced before they are able to reliably take skinfold measurements.

A good tool to measure is the circumference of the client's abdomen, arm, buttocks/hips, calf, forearm, hips/thigh, mid-thigh, and waist. Taking these measurements gives trainers a more accurate starting point for overweight and obese clients. For a start, measuring just the waist and hips can often be enough to get a rough idea of where a client is at.

Keeping in mind the inaccuracy of BMI, it is a helpful tool to develop achievable goals with overweight clients. A BMI of 18.5 to 24.9 is considered within a normal range, 25-29.9 is considered overweight, and a BMI of 30 or greater is obese.

As stated above, over 31% of Americans are obese, meaning their BMI falls into a range of 30 and above. This population-level increase in BMI leads to a corresponding increase in the various metabolic conditions associated with obesity.

Obesity and Exercise

Weight loss results derive from calories in versus calories burned and when excess calories are not expended, they are converted and stored as fat. While traditional advice would have trainers tell their clients to “eat less, run more,” there are additional environmental factors that contribute to overeating and decreased activity levels.

The availability of low-cost, calorie-dense, micronutrient-poor foods is a contributing factor along with a decrease in physical activity in both occupation and recreational activities.[21] Personal trainers should work closely with dietitians to develop a balanced lifestyle that encompasses both a training program and a nutritional program.

Regardless of muscular strength, overweight and obese individuals tend to exhibit poor balance, slower gait velocity, and shorter steps.

Training should be focused on energy expenditure, balance, and proprioceptive training to burn more calories and improve posture, and gait.[22]

By programming proprioceptive exercises, there is greater potential for caloric expenditure, stability training, and greater muscle recruitment.[23]

For weight loss results, obese clients should expend 200 to 300 kcal per exercise session with a weekly average starting at 1200 kcal expended between physical activity and exercise.

Having clients start on an aerobic workout regimen is ideal for sustainability. Resistance training should be added into a training program starting at a lower intensity and employing modifications where necessary.

For obese clients who are hesitant to begin resistance training, taking increasingly longer walks is a good way to begin exercising.

However, incorporating some resistance training is important in a weight loss program because it helps increase lean body mass, which over time will improve metabolic function and overall body composition.[24]

Recommendations for Training Obese Clients

Frequency

- 5+ days per week to maximize caloric expenditure

Intensity

- Moderate to vigorous intensity for aerobic activity- progress to vigorous activity once sustainability is accomplished

Time

- Minimum 30 minutes, progressing to 60 minutes of moderate, aerobic activity
- Incorporate vigorous exercise only if the client is capable and willing to increase the intensity

Mode

- Primary should be aerobic exercises and weight lifting that involve large muscle groups

Assessment

- Push, pull, squat, single leg balance

Special Considerations

Weight management relies on the relationship between energy intake and energy expenditure. However, a deeper look into the environmental effects on weight loss are important to note because sustainable weight loss will only be achieved if relative factors are addressed.

To achieve weight loss, clients should aim to decrease current energy intake by 300-500 kcal, and progress to a minimum of 150 minutes of moderate intensity aerobic activity to optimize health. Increase exercise gradually for sustained weight loss.

Programming Guidelines for Obesity

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-5 days per week	5 or more days per week to maximize caloric expenditure
Mode	Targeting each muscle and tendon using active, passive, and dynamic forms of stretching	Free weights, machines, or resistance bands	Primary should be aerobic exercises that involve large muscle groups
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	1-3 sets of 8-12 repetitions for each muscle group	Minimum 30 minutes, progressing to 60 minutes of moderate, aerobic activity, incorporate vigorous exercise only if the client is capable and willing to increase the intensity.
Intensity	Medium tension in the muscle	5-6 (moderate) or 7-8 (vigorous) on a 10 point scale depending on level and progression	Moderate to vigorous intensity for aerobic activity- progress to vigorous activity once sustainability is accomplished

Training Guidelines for Diabetes

Diabetes is the seventh leading cause of death in America.[25] Diabetes is a metabolic disorder that affects how the body converts food into energy. The human body breaks down most food into sugar (glucose) and releases it into our bloodstream.

When there is an excessive amount of sugar, it signals the pancreas to release insulin and insulin allows blood sugar into cells to be used as energy. A person with diabetes does not produce enough insulin (type 1) or the body does not respond to the insulin that is being produced (type 2).

A primary characteristic of type 1 diabetes is insulin dependency while type 2 diabetes is caused by insulin-resistant skeletal muscle, adipose tissue, and liver, combined with an insulin secretion deficit. A common cause of type 2 diabetes is excessive body fat with fat distributed in the upper half of the body.

However, some individuals may not be able to control their glucose levels, thus becoming insulin-dependent.[26] To control the high levels of blood sugar, type 1 diabetics inject insulin to produce what the pancreas cannot.

Exercise increases the rate at which people utilize glucose, meaning insulin levels may need to be adjusted when performing the exercise.

It is important to control insulin levels before, during, and after exercise, because when blood sugar becomes too low, it creates a condition called hypoglycemia (low blood sugar) which can make the individual feel light-headed, dizzy, and short of breath.

Type 2 diabetes develops gradually and years can pass before severe symptoms arise. This is often called adult-onset diabetes and accounts for 90-95% of those with diabetes.[27] With insulin resistance, the body cannot effectively use the insulin in the muscles or liver even though it produces a sufficient amount.

Over time the pancreas cannot secrete the insulin effectively to compensate for insulin resistance and hyperglycemia (high blood sugar). Genetic factors are a cause of type 2 diabetes, however, most people with this type are overweight or obese at the onset of symptoms.

Exercising with Diabetes

The fundamental goal for management of diabetes mellitus is glycemic control using diet, exercise, and, in many cases, medications such as insulin or oral hypoglycemic tablets.

More specifically, when focusing on individuals with type 2 diabetes, the main goal would be weight loss. By exercising the skeletal muscle, the body circulates glucose, creating a similar effect to insulin, thereby reducing insulin requirements.

Special Considerations

Hypoglycemia during exercise is the most common and serious problem in individuals with diabetes, especially for individuals who are taking oral medications or supplemental insulin. Rapid drops in blood sugar may occur in exercise, even when blood sugars are at a normal level. Common symptoms associated with diabetes include weakness, dizziness, shakiness, excessive sweating, anxiety, tingling, and hunger.[6] Tracking an individual's glucose levels throughout the program is necessary to maintain consistent levels.

Exercise should be scheduled knowing the client's insulin timing to prevent hypoglycemic episodes along with adjusting carbohydrate intake before and after the workout to avoid hypoglycemic episodes.[24] Recommend individuals with diabetes to exercise with a snack to avoid lowering their blood sugar.

Exercise Recommendations for Individuals with Diabetes

Frequency

- 3-7 days per week

Intensity

- Aerobic goal is 40%-60% maximum heart rate, however better glucose control may be achieved during higher intensity exercises, so intensity should increase progressively over time.

Duration

- 20-60 minutes or a minimum of 150 minutes per week

Mode

- Low impact activities (walking, cycling, progress into swimming)

Resistance Training

- 1-3 sets of 10-15 repetitions, 2-3 days per week

Assessment

- Push, pull, OVH Squat, single-leg balance, and single-leg squat

Programming Guidelines for Diabetes

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	3-7 days per week
Mode	Targeting each muscle and tendon using active, passive, and dynamic forms of stretching	Free weights, machines, or resistance bands	Low impact activities (walking, cycling, progress into swimming)
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	1-3 sets of 10-15 repetitions for each muscle group	20-60 minutes or a minimum of 150 minutes per week
Intensity	Medium tension in the muscle or a deep stretch, depending on level and progression	5-6 (moderate) or 7-8 (vigorous) on a 10 point scale depending on level and progression	Aerobic goal is 40%-60% maximum heart rate, however better glucose control may be achieved during higher intensity exercises, so intensity should increase progressively over time

Training Considerations for Hypertension

Hypertension, commonly referred to as high blood pressure, is among the most common modifiable cardiovascular disease risk factors. Blood pressure is the pressure measured within large blood vessels, especially the arteries.

This pressure fluctuates depending on the strength of the heartbeat, the elasticity of the arterial walls, the volume and viscosity of the blood, as well as the person's age, physical condition, and health. Blood pressure has two categories: systolic and diastolic.

The systolic (top number) measures the maximum pressure the heart exerts while beating, while the diastolic (bottom number) measures the pressure in the arteries between beats. A normal resting blood pressure used to read 120/80mmHg, however new guidelines by the American Heart Association suggest a healthy BP is "less than 120/80 mmHg." Individuals classified with hypertension have a resting BP of 140 mmHg or greater or a resting diastolic BP of 90 mmHg or greater.

Personal trainers should know whether their clients are taking hypertensive medication before starting any exercise program. Hypertension increases cardiovascular risk factors such as disease, stroke, heart failure, peripheral arterial disease, and chronic kidney disease. Medications are proven highly effective. However, lifestyle changes such as increased physical activity, diet, and quitting smoking have also been proven to decrease hypertension.

Aerobic exercise training leads to reductions in resting BP by nearly 5-7 mm Hg in individuals with hypertension.[27] If personal trainers are able, they should measure their client's blood pressure and heart rate before and again after the workout. These results should be logged during each session. Personal trainers should focus on aerobic activities for clients with hypertension, supplemented with moderate intensity resistance training.

Body position is extremely important when measuring heart rate or blood pressure. The client should not talk during measurements. They should sit upright in a chair with both feet flat on the ground for accurate results. Training regimens should be performed in a circuit-style to distribute blood flow between the upper and lower extremities. Clients should focus on deep breaths during exercise and avoid the Valsalva maneuver.

Exercise Recommendations for Individuals with Hypertension

Frequency

- Aerobic exercise on most, preferably 6-7 days per week, resistance training 2-3 days per week

Intensity

- Moderate intensity aerobic exercise (40-60% MaxHR) supplemented with resistance training at 60-80% 1-RM.

Duration

- 30-60 minutes of continuous aerobic exercise

Mode

- Emphasis should be placed on aerobic activities such as walking, cycling, or swimming. Resistance training should utilize free weights, machines, or resistance bands.

Movement Assessment

- Push, pull, OVH Squat, Single leg balance

Flexibility

- Static and active stretches in a standing or seated position

Special Considerations

Avoid heavy lifting and the Valsalva maneuver. Do not perform the cardiovascular exercise if resting systolic BP exceeds 200 mmHg or diastolic BP exceeds 110 mmHg.

Programming Guidelines for Hypertension

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	Aerobic exercise preferably 6-7 days per week
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Free weights, machines, or resistance bands	Walking, cycling, or swimming
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	1-3 sets of 8-12 repetitions for each muscle group	30-60min. of continuous aerobic exercise
Intensity	Medium tension in the muscle or a deep stretch, depending on level and progression	5-6 (moderate) on a 10 point scale	Moderate intensity aerobic exercise (40-60% MaxHR)

Training Considerations for Coronary Heart Disease

Approximately every forty seconds, a person has a coronary infarction (heart attack) in the United States.[28] Fifty percent of all cardiovascular deaths are a result of coronary heart disease (CHD) making it the leading cause of death in both men and women.

CHD is caused by plaque formation or atherosclerosis. Plaque builds in the carotid, iliac, femoral, and aortic arteries, causing the narrowing of the blood vessels, which leads to poor perfusion and ultimately, heart failure.

The rate of progression of atherosclerosis may not be consistent, but there are several causes of plaque build up such as tobacco usage, low-density lipoprotein cholesterol, hypertension, diabetes mellitus, and various infectious agents.[6, 29, 30]

The goal of the fitness trainer in helping clients with CHD is to stabilize the buildup of plaque through a lifestyle change incorporating exercise, good nutrition, and adequate sleep.

Though moderate exercises are recommended for these patients, research indicates high-intensity interval training has significant increases on VO_2 max, improvements in endothelial function, and lower resting blood pressure.[31]

Before beginning a training program, clients should be cleared by their physician for exercise. If the client has had an episode or myocardial infarction, they may have already completed a cardiac rehabilitation program. Trainers must stay up to date on medications their clients are taking and learn the signs and symptoms of a heart attack.

It is important for trainers to speak with clients about the benefits of participating in an exercise and nutrition program to improve their condition. A proper lifestyle change that incorporates exercise and nutrition can lower the risk of death, increase exercise tolerance, raise muscle strength, reduces CHD, and overall improves physiological health.

The risks of injury are low for individuals with CHD, however clients should be able to track their heart rate reliably and stay below their maximum allowed exertion as determined by their physican

Signs of CHD vary between individuals. However, if a client experiences chest pain, exercise should be stopped and the client should be assessed. Individuals with CHD may also have comorbidities, such as diabetes, hypertension, and obesity, so trainers must comprehensively screen clients to develop proper modifications.

Exercise Recommendations for Individuals with Coronary Heart Disease

Frequency

3-5 days per week

Intensity

Moderate: 40-85% Maximum HR

Duration

- 30 minutes per day of moderate intensity 5 days per week or 20 minutes of vigorous intensity 3 days per week

Mode

- Circuit training for large muscle groups, walking, cycling, group glasses

Movement Assessment

- Push, Pull, OH Squat, Balance

Flexibility

- Static or active stretching

Special Considerations

Be aware that individuals with CHD may also have comorbidities such as diabetes, hypertension, peripheral vascular disease, and/or obesity. Regress exercises if needed, such as training using a chair if necessary. Encourage regular, adequate breathing— avoid the Valsalva maneuver.

Training Considerations for Osteoporosis

Osteoporosis is a skeletal disorder characterized by low bone density and deterioration of bony tissue,[32] whereas osteopenia also indicates bone density loss, just at a lower level. In order to understand osteoporosis, it is first necessary to learn the physiology of bone formation, also known as bone remodeling. Over a person's lifespan, bone remodeling maintains the architecture and structure of bones, regulates calcium level, and prevents fatigue damage.[34]

Bone mineral density increases during adolescence and begins to decrease after the age of forty. Bone loss occurs at a greater rate in women than men because women start with naturally lower bone density and their rate of bone loss increases 3-5 years after menopause. As such, women develop osteoporosis more often than men. Osteoporosis affects almost 50 percent women at some point in their life.[33]

A loss in bone density directly correlates to bone fractures and leads to increased morbidity and mortality.[6] There are two main types of osteoporosis. Type 1 osteoporosis is developed as a result of natural aging, including lower productions of estrogen and progesterone, both of which are key components of regulating bone loss.

While type 1 is primarily due to the normal course of aging, type 2 encompasses other medical risk factors, medications, and lifestyle factors such as tobacco smoking and alcohol consumption. Both forms of osteoporosis are treatable.

The development of osteoporosis and osteopenia is asymptomatic, which leaves the disease undetected. Bone mineral density assessments are not always accurate. Often, a fracture is the first time the disease is detected. Before training a client with osteoporosis, it is imperative to obtain a history of their fractures and current bone mineral density.

Knowing this information will help develop a proper exercise program and minimize mechanical stress on the hip, spine, or wrist, which are at the highest risk. Other risk factors associated with osteoporosis development include physical inactivity and low calcium intake.

Fitness professionals must be aware of the contraindications for clients with osteoporosis. The impact associated with traditional exercise movements may be excessive. As such, spinal flexion, high impact skeletal loading such as jumping, and stepping should be avoided along with twisting movements of the neck and spine.[24]

Gait and balance will have an effect on individuals with osteoporosis due to spinal fractures and joint impingements from bone deterioration, therefore client programs should include low intensity exercises.

Increasing physical activity improves bone mineral density and strength. Additionally, training adaptations typically improve balance, which reduces the risk of falling.

When training a client with osteoporosis, it is important for coaches to learn their client's abilities and limitations. Though resistance training has been shown to improve bone density, they must assess to see if a specific exercise would improve their clients' conditions or lead to a fracture. This is also the case when conducting movement assessments.

If a client is capable of standing, then performing exercises such as push, pull, and overhead squat movements are appropriate. Otherwise using exercise equipment to assist with the movement assessment will be helpful.

An exercise program for clients with osteoporosis should create variable weight distributions on the bones and focus on strengthening the main joints that become overloaded like the hips, spine, wrists, and lower back.[35] An exercise program should not be substantially different than that of a normal individual of the same age.

Exercise Recommendations for Individuals with Osteoporosis

Frequency

- 2-5 days per week of aerobic exercise and 2 days per week of strength training

Intensity

- Moderate intensity to begin (40-70% HR Max) or 15 reps of 8-10 exercises for strength training

Duration

- 30 minutes of aerobic training or 30-60 minutes of resistance training

Mode

- Walking, biking, weight machines, resistance bands, dumbbells

Special Considerations

Avoid jogging and other exercises that increase the risk of falling. Avoid spinal flexion and rotation. Encourage slow and controlled movements to maintain proper form. Focus exercises on strengthening target joints: hips, lower back, wrists, and spine.

Osteoporosis is not a contraindication to exercise. In fact, exercising helps increase bone mineral density and improve quality of life. It is important to build confidence in a client's balance so they feel safe performing everyday duties.

A health report should be obtained from the individual so the trainer can develop an exercise program appropriate to their abilities. Flexibility should be limited to static and active stretching, using a chair if necessary. Develop exercise programs with longevity and progression in mind as it takes time to improve bone mineral density.

Programming Guidelines for Osteoporosis

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	2-5 days per week of aerobic exercise
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Weight machines, resistance bands, dumbbells	Walking, biking
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	15 reps of 8-10 exercises for strength training targeting each muscle group, 30-60 minutes of resistance training	30 minutes of aerobic training
Intensity	Medium tension in the muscle or a deep stretch, depending on level and progression	5-6 (moderate) on a 10 point scale	Moderate intensity to begin (40-70% HR Max)

Training Considerations for Arthritis

Arthritis is an acute or chronic inflammation in one or more of the joints. There are a wide variety of symptoms associated with arthritis such as joint stiffness, pain, decreased range of motion, and joint deformities.[36]

There are over 100 different forms of arthritis, all varying in degrees of joint mobility, deterioration of the muscle tissue, and pain.

The two most common types personal trainers will encounter with clients are osteoarthritis (OA) and rheumatoid arthritis (RA). In both conditions, exercise has a major impact on those living with the disease. Exercise helps to support the affected joint by building strong supportive muscles around the joint.

Osteoarthritis

Osteoarthritis involves degeneration of the cartilage within joints, which develops gradually and particularly affects the articulating bones.

Constant movement with diminishing cartilage causes bone-on-bone rubbing, inflammation around the joint, and weakening of ligaments and tendons. Symptoms of OA include stiffness, deformities, crepitus, and bone spurs.

The most affected areas include large weight-bearing joints such as the hips and knees, the hands, feet, and the spine.

Rheumatoid Arthritis

Rheumatoid arthritis is an autoimmune disorder that begins affecting the small joints first, then larger joints, and eventually the organs. This disease destroys the cartilage in joints, causes joint stiffness, inflames the ligaments and tendons, and is very painful for individuals.[37]

Movement assessments should analyze the joint function and should be reassessed throughout the client’s exercise program to monitor their arthritis and symptoms.

Pain will be a major barrier when beginning or maintaining a program, therefore the goal should be to avoid painful movements while also keeping the program relevant.

Exercise programs can interact at each stage of arthritis and can help mitigate the effects of the disease on the deterioration of physical development. It is recommended clients follow a program that develops strength and stability to improve balance and joint strength.

Trainers will likely encounter deconditioned individuals with this disease so it is ideal for them to start their training with flexibility in the seated position before progressing to standing. Throughout the workout, trainers should ask the client if they are experiencing flare-ups, heat, or pain and adjust the workout accordingly.

Exercise Recommendations for Individuals with Arthritis

Frequency

- Aerobic exercise 3-5 days/week, resistance exercise 2-3 days/week

Intensity

- 40-60% Max HR- light to moderate intensity- both light and higher intensity both show improvements in joint function, pain, and strength of the muscle

Duration

30 minutes per day

Mode

- Aerobic exercise with low joint stress- walking, cycling, swimming.
- Resistance exercise should include all major muscle groups and flexibility exercises for all range of motion in all muscle groups.

Special Considerations

Avoid strenuous exercises during flare ups and when highly inflamed. Adequate warm up and cool downs help to wake up the joints and invite movement into the body. Avoid heavy lifting to protect the bone structure.

Programming Guidelines for Arthritis

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	Aerobic exercise 3-5 days/week
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Resistance exercise should include all major muscle groups and flexibility exercises for all range of motion in all muscle groups	Aerobic exercise with low joint stress- walking, cycling, swimming
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	8-15 reps of 8-10 exercises for strength training targeting each muscle group	30 minutes per day
Intensity	Medium tension in the muscle or a deep stretch, depending on level and progression	Both light and higher intensity both show improvements in joint function, pain, and strength of the muscle	40-60% Max HR- light to moderate intensity

Training Considerations for Cancer

Cancer describes a range of diseases characterized by an uncontrollable growth of abnormal cells that divide and spread through other organ tissues. Cancer management modalities involve surgery, radiation, chemotherapy, hormones, and immunotherapy.[39]

Clients who are going through any of these treatments during training may experience side effects that may limit their ability to complete workouts due to a decrease in overall physical function, muscular strength, and joint range of motion.

In recent years, studies have shown that regular moderate intensity exercise enhances immune function, which lowers the susceptibility to cancer.

Long term effects of exercise promote anti-inflammatory effects because of the reduction in body fat and release of catecholamines.[40]

Personal trainers should have an overall understanding of how to develop an exercise regimen for this population and should judge their clients abilities in strength, balance, flexibility, and mobility.

Exercise at a moderate intensity for moderate durations has a positive effect on the immune system and research shows that moderate to high intensity activity is associated with a decrease in mortality in certain forms of cancer.

Individuals with cancer typically experience fatigue and weakness quicker than healthy individuals. Exercises should be primarily aerobic based at low- moderate intensity with many breaks. Exercise duration, frequency, and intensity should be progressed slowly as tolerated by the client.

The American College of Sports Medicine guidelines for cancer survivors does not state any differences in training individuals that are healthy post-cancer, so an exercise program for otherwise healthy cancer survivors should include flexibility, resistance, and aerobic training.[24]

Exercise Recommendations for Individuals with Cancer

Frequency

- 3-5 days per week

Intensity

- 50-85% of Max HR

Duration

- 15-30 minutes per session (start low and slowly progress 30 seconds- 2 minutes per day)

Mode

- Walking, stationary bike, free weights, resistance bands

Special Considerations

Intensity may need to be adjusted during exercise. If needed, conduct a few exercises multiple times per day. Allow for adequate rest between sets.

Programming Guidelines for Cancer

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	3-5 days per week
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Machines, resistance bands, free weights	Walking, stationary bike
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	30 minutes per session (start low and slowly progress)	15-30 minutes per session (start low and slowly progress 30 seconds- 2 minutes per day)
Intensity	Stretch to the point of slight discomfort	3-4 (low) up to 5-6 (moderate) on a 10 point scale	50-85% of Max HR

Training Considerations for Chronic Lung Disease

Chronic lung disease includes, chronic obstructive pulmonary disease (COPD), sleep-disordered breathing, and interstitial lung disease. Smoking is a primary risk factor for developing chronic lung disease and though cigarette smoking is on the decline, there is significant data that shows the negative effects of vaping and e-cigarettes on lung function.[41]

There are two major types of chronic lung disease: restrictive and obstructive. Restrictive lung disease is categorized by a reduced playability of the lung tissue; compromising lung expansion by reducing lung volumes, which decreases total lung capacity.

Obstructive lung diseases revolve around blockages in the air passageways that limit ventilation.

Major obstructive lung diseases include asthma, chronic bronchitis, and emphysema. Mucus builds in the lungs and air passages which leads to chronic inflammation that obstructs the airway. Chronic lung diseases are developed throughout life, so even though cystic fibrosis is a lung inflammatory disease, it is also a genetic disorder.

Exercise training has been shown to improve lung function and lung tissue in individuals with lung disease. Exercise increases functionality and though there is a decrease in ventilation and gas exchange for these individuals, it is possible to program to their tolerance.

Individuals with lung disease will experience shortness of breath which may then lead to dizziness so being mindful of intensity levels is key to developing an appropriate resistance and aerobic workout. Individuals with emphysema typically are underweight and experience shallow breathing because of a lack of neck and upper back muscles. On the contrary, individuals with chronic bronchitis are typically overweight with a large chest.[6]

Training methodologies for individuals with lung disease are similar to that of a healthy person. Clients exercising with lung diseases will fatigue sooner. Exercising lung function will strengthen the diaphragm that helps fill the lungs, and decrease symptoms of dyspnea, or shortness of breath.

Developing an exercise regimen utilizing resistance of the lower body is an excellent starting point since upper body exercises will require additional support of the muscles in the lungs.

Progress slowly and begin training at a low intensity and breath focus. Clients in this population are typically on medications or inhalers to open the bronchioles and alveoli of the lungs.[42, 43] It is important to know what these medications are, trainers should have them bring their medications for each session and learn how these medications will affect the training.

There are a few considerations when training individuals with chronic lung disease. Arm exercises require accessory muscles of inspiration so programming lower extremity exercises will help to develop lung function but will not fatigue the client preemptively.

A workout regimen aimed at improving lung function through resistance training could benefit those with obstructive lung disease through training 2-3 days per week at 30 minutes in duration with low resistance. Another consideration for those with lung disease is deconditioning of the muscles and lungs.

Depending on which type of lung disease they have, they may be overweight, underweight, or not active so exercise programming should revolve around the clients' shortness of breath and tolerance.

If clients are using supplemental oxygen during a workout, trainers should not adjust their flow. This is considered a medication and if the client is experiencing shortness of breath, exercise should stop and their physician should be consulted.[6]

Exercise Guidelines for Individuals with Lung Disease

Frequency

- 1-2 sessions, 3-5 days per week

Intensity

- 40-60% of Max HR, comfortable pace and endurance (monitor dyspnea)

Duration

- 30 minute sessions

Mode

- Large muscle activities- walking, swimming, cycling and free weights, machines for resistance training

Special Considerations

Exercise compliance should be considered in the determination of exercise intensity. Shorter intermittent sessions may be necessary initially. Respiratory muscle weakness is common. Upper body exercises contribute to dyspnea and inspirations muscle may require training.

Programming Guidelines for Chronic Lung Disease

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week with low resistance	1-2 sessions, 3-5 days per week
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Free weights, machines for resistance training	Large muscle activities- walking, swimming, cycling
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	30 minutes	30 minute sessions
Intensity	Stretch to the point of slight discomfort at first, then progress to medium tension or a deep stretch as needed	Start with 3-4 (low) up to 5-6 (moderate) or 7-8 (vigorous) on a 10 point scale depending on level and progression	40-60% of Max HR, comfortable pace and endurance (monitor dyspnea)

Training Considerations for Peripheral Artery Disease

Peripheral artery disease (PAD) occurs as the result of developing atherosclerotic plaque in the internal walls of the major arteries in the legs. This disease decreases functional capacity in oxygenated blood flow, increases the risk of cardiovascular diseases, and is associated with a higher risk of mortality.

Individuals can be asymptomatic or experience symptoms associated with PAD including intermittent claudication (IC) which encompasses pain, cramping, and aching in the calves, thighs, or buttocks. It may be difficult to distinguish deconditioning and PAD, so if clients complain about these symptoms, it is best to have them see their physician first.

Some traditional risk factors associated with PAD include advanced age, smoking, obesity, diabetes, hyperlipidemia, and hypertension.[44] It is important to know that PAD often comes with other comorbidities and is associated with obesity, coronary heart disease, and diabetes so exercise can significantly help control and even lower the risk of these morbidities.

A properly developed training program should increase exercise performance by increasing oxygen consumption by 15-30%, increasing walking ability and quality of life. Regular exercise increases leg blood flow and reduces blood viscosity, so it does not pool in the lower extremities.

There are several training considerations to follow for individuals with PAD. Beta-blockers decrease the time to claudication so understanding which medications clients are taking is important for programming. Cold weather exacerbates pain, so trainers should exercise clients in a warm environment, when possible.

When clients have a known coexisting coronary disease or diabetes, coaches will have to adjust the intensity and maximum heart rate. Resistance training promotes claudication so it should be in addition to aerobic exercising and always to the client's pain tolerance.[6, 45]

Exercise Guidelines for Individuals with Peripheral Artery Disease

Frequency

- At least 3 days per week

Intensity

- 50-85% maximum heart rate

Duration

- Work up to 35-50 minutes

Mode

- Walking exercise, stationary cycling, and/or elliptical trainer

Special Considerations

- Begin exercise at 5-10 minutes and increase from there.
- For asymptomatic PAD, IC may not be a duration-limiting factor so the level of exertion should be used to guide exercises.
- Allow for sufficient rest between sets.

Programming Guidelines for Peripheral Artery Disease

	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	At least 3 days per week
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Free weights, machines for resistance training	Walking exercise, stationary cycling, and/or elliptical trainer
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	30 minutes	Work up to 35-50 minutes
Intensity	Stretch to the point of slight discomfort at first, then progress to medium tension or a deep stretch as needed	Start with 3-4 (low) up to 5-6 (moderate) or 7-8 (vigorous) on a 10 point scale depending on level and progression	50-85% maximum heart rate

Training Considerations for Nonspecific Low Back Pain

Nonspecific low back pain (NSLBP) remains a condition that many people in society suffer from. It is the most musculoskeletal complaint in the world with 85% of people complaining about NSLBP in their lives. This condition does not only affect individuals physically, but also mentally and socially. When the symptoms of NSLBP affect ability to move, then someone's ability to socialize decreases, and chances of depression significantly increase.

This topic is listed under special populations because each client trainers encounter with NSLBP may have different symptoms and should always be monitored for inflammation, additional pain, or new symptoms. NSLBP includes pain in the lumbosacral area that is not attributed to any known or recognizable disorders such as tumors, osteoporosis, inflammation, deformities, disc disease, or spinal compression.[46]

There are three subtypes of NSLBP that account for the duration of the pain:

1. Current: less than 6 weeks
2. Sub-acute: 6-12 weeks
3. Chronic: 12 weeks or more

Treatment to find out the cause of back pain includes medical interventions and screenings such as x-rays or MRI.

There are many tendons, ligaments, and nerve roots flowing through the lower back that makes diagnosing difficult to narrow down. Disc deformities can be a factor in NSLBP and a medical screening should be obtained before beginning an exercise prescription.

A client with NSLBP may complain of generalized pain in the lumbosacral region. Pain will differ between individuals in intensity, duration, and frequency. Some may experience radiating pain with sensory changes, numbness, or lower extremity weakness.

Research states that individuals with NSLBP have decreased activation of certain intrinsic core muscle groups including the transverse abdominis, internal obliques, pelvic floor muscles, multifidi, diaphragm, and deep erector spinae.[47]

In addition to a decrease in core muscle activation, individuals with NSLBP tend to have decreased muscular endurance, and trunk muscle weakness. Promoting exercise to strengthen the lower back is strongly suggested to help alleviate the pain and avoid bed rest, however weight bearing activities can increase symptoms in certain planes of motion and postures.

Before executing exercises, it is vitally important to explain and demonstrate how to locally and globally stabilize the core, because, if not properly addressed, exercises can increase pressure on the discs and can cause damage to ligaments and supporting vertebrae.

A general rule is to strengthen the muscles of the core first before strengthening to outer extremities. Strengthening the muscles of the core should be progressive and have longevity in mind.[48]

Training considerations vary case by case however prevention should be considered for clients with NSLBP to decrease the chance of the pain returning. If the client is having an acute flare-up trainers should not perform any exercises and mandate a brief rest period for the client.

Individuals will experience pain in different ways so sitting on a bike may not be comfortable for some, and walking on a treadmill could cause pain for others. Fitness professionals must work closely with the client to find exercises that will promote stability and strength in the core.

Adherence to exercise may be difficult to achieve with individuals suffering with chronic NSLBP, but functionality can improve quickly, and long term benefits begin after only two months of training. Exercise should be generally tolerable and should only leave clients mildly sore.

Exercise Guidelines for Individuals with Nonspecific Low Back Pain

Frequency

- 3-5 days per week- progress to everyday

Intensity

- Moderate 40-60% maximum HR

Duration

- Build up to 20-60 minutes, 10-minute bouts throughout the day

Mode

- Brisk walk with arm movement, cycling (if possible), swimming

Special Considerations

- Low impact is best initially.
- Individuals are typically deconditioned so start low and slow, progress as tolerated.
- Avoid exercising on unstable surfaces (stability ball) early in training.
- Monitor symptoms and pain tolerance levels, adjust workout accordingly.

Programming Guidelines for Nonspecific Low Back Pain			
	Flexibility	Resistance Training	Aerobic Training
Frequency	Before and after each activity or exercise session	2-3 days per week	3-5 days per week- progress to everyday
Mode	Targeting each muscle and tendon using active and passive forms of stretching	Bodyweight, free weights, machines for resistance training	Brisk walk with arm movement, cycling (if possible), swimming
Volume	5-30 minutes total with 2 x 30 second bouts for each muscle group	30 minutes	Build up to 20-60 minutes, 10-minute bouts throughout the day
Intensity	Stretch to the point of slight discomfort at first, then progress to medium tension or a deep stretch as needed	Start with 3-4 (low) up to 5-6 (moderate) or 7-8 (vigorous) on a 10 point scale depending on level and progression	Moderate 40-60% maximum HR

Summary

Special populations clients are frequently encountered in the personal training setting. Well-trained fitness professionals have the ability to modify and deliver fitness programs to a variety of clients. As such, knowledge of special populations training protocols is key for certified personal trainers.

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Chapter 24

Basic Nutritional Concepts

Ellen Landes, MS, RDN

Introduction

Knowledge of basic nutritional concepts is important for personal trainers as nutrition plays an integral role in the overall mechanics and health of the body. This chapter will review nutrition and its importance for athletic performance, foundational concepts in nutrition, popular diets, and general healthy eating guidelines.

Nutrition can be defined as the science of the nutrients in foods and their impact on the body. Taking the definition of nutrition a step further considers dietary choices and relevant human behaviors.[1]

Importance of Nutrition for Health and Athletic Performance

Poor nutrition is one of the leading risk factors when it comes to both chronic disease as well as death in the United States.[2]

Large studies of over 2.88 million patients in total have all provided the same information – that being overweight or obese greatly increases the risk of death from chronic conditions such as cardiovascular disease, kidney disease, and diabetes.[2]

Of course, other factors play a role in the development of diseases.

It’s possible to have a genetic predisposition for conditions such as type 2 diabetes; however, research supports the concept that a healthy lifestyle can help with prevention of diabetes, despite any predisposition. [2]

From a fitness standpoint, optimal nutrition can enhance athletic performance as well as provide proper recovery from exercise.[3] It’s clear that nutrition plays a key role in all aspects of health and personal trainers will need to have a basic understanding of its concepts to be successful in working with clients.

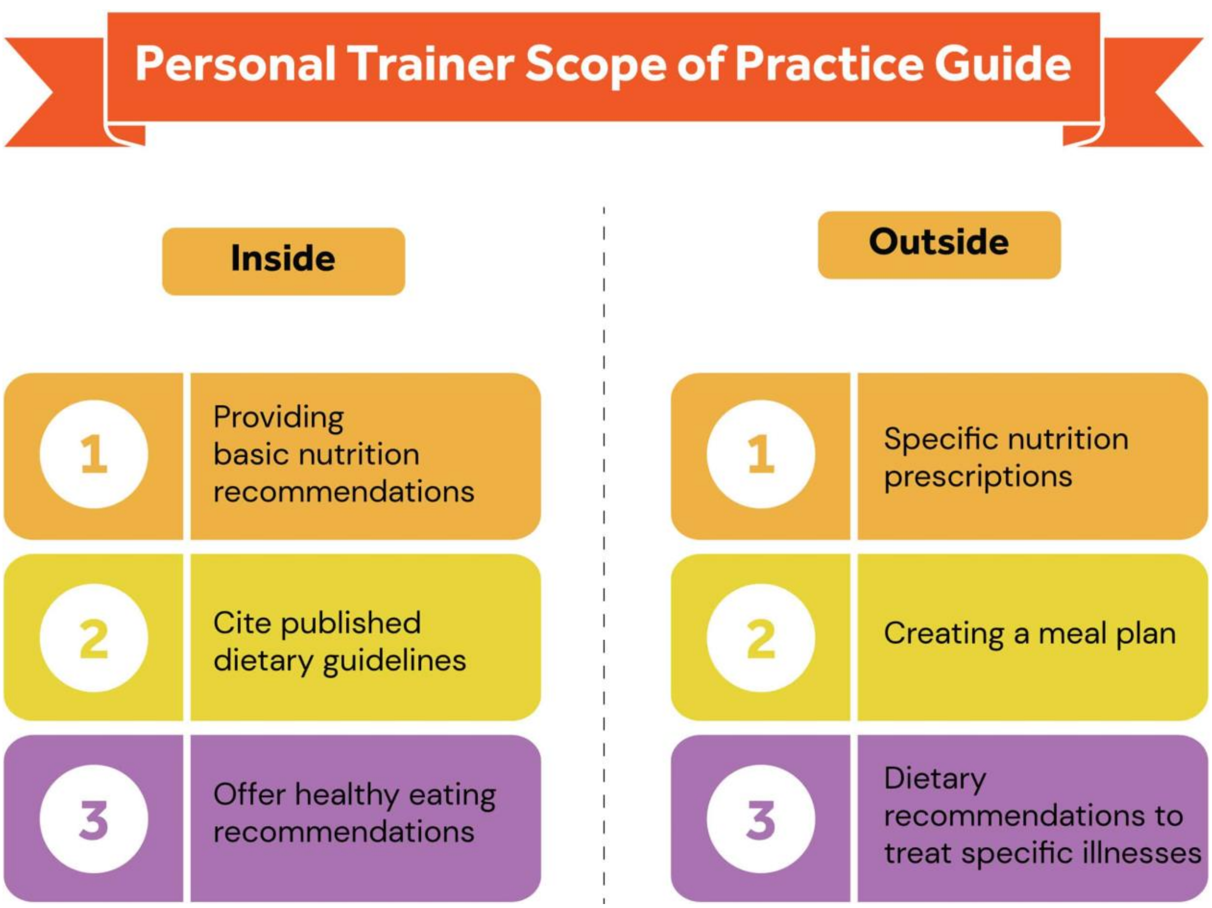
The Trainer Academy CPT Scope of Practice

Personal trainers must respect their scope of practice when it comes to nutrition. In most states, there are laws in place that prevent individuals without the proper licensing and certifications from providing specific nutrition services, such as meal plans or recommendations for specific diseases.

Registered Dietitians or Registered Dietitian Nutritionists (RDs or RDNs) are individuals who earn bachelor's degrees in nutrition and dietetics from accredited colleges or universities, complete a supervised clinical practice internship, pass a national examination, and maintain continuing education credits.

Because of their in-depth experience and qualifications, only RDs are legally allowed to provide specific nutrition prescriptions.[4]

However, personal trainers can provide basic nutrition recommendations and cite published dietary guidelines without specifically assigning certain foods. Overall, giving nutrition recommendations within the personal trainer scope of practice may be beneficial for their clients.



Basic Nutrition Concepts

Metabolism and Bioenergetics

One of the first steps in understanding nutrition and its effects on the body is to learn about energy balance. This becomes important in the role of the personal trainer, especially when clients are looking to lose or gain weight.

A calorie is a measurement of heat energy. The energy in food is measured in calories, and denominated kilocalories. Technically speaking, one kilocalorie is the amount of heat (energy) that is needed to raise the temperature of 1 kilogram (kg) of water by 1 degree Celsius.

However, most people refer to the energy found in food as simply "calories". This textbook will use the abbreviation "kcal," or the term "calories" moving forward to discuss energy intake and expenditure.[5]

Energy balance occurs when energy intake (in the form of calories from food) is roughly equal to energy expenditure (or the calories burned throughout the day). When energy is balanced, body weight remains stable. When a negative energy balance exists, meaning energy intake is less than the energy expended, body weight decreases.

Alternatively, in a state of positive energy balance, when calories eaten (energy intake) are greater than the calories being burned (energy expenditure), body weight increases.[6] It's worth noting that while this concept is indeed simple, it's not always easy for those seeking to gain or lose weight. Obesity rates have increased over the years in part thanks to an environment with an abundance of highly palatable foods and societal decreases in physical activity.[6]

Total Daily Energy Expenditure (TDEE)

Total Daily Energy Expenditure, or TDEE, is the amount of energy that is expended in a 24-hour period. It's a dynamic number that is affected by various factors day to day, including activity levels, the environment, caffeine, sleep, and other lifestyle factors.[1]

TDEE consists of three main components: the basal metabolism, physical activity, and the thermic effect of food.

The thermic effect of food (TEF) is the energy that is required to process the food consumed and will account for about 10% of total energy expenditure.[1]

When food is ingested, the body needs to use energy to break it down to digest and absorb it. Interestingly, protein, when compared to carbohydrates and fats, has the highest thermic effect on food, increasing the metabolism an estimated 15-30% after ingestion. For reference, carbohydrates cause an increase of about 5-10% and fats just 0-3%.[7, 8]

Arguably the most variable component of TDEE among different individuals, as well as within one individual day to day, is physical activity, which can account for anywhere from 30 to 50% of someone's energy expenditure.

A person's physical activity is the amount of voluntary movement they are performing each day. This includes any form of movement, such as an active day job. For example, a mail delivery carrier has a certain amount of physical activity he or she performs every day through their job which contributes to their energy expenditure as well as any formal exercise they perform.[1]

NEAT, or Non-Exercise Activity Thermogenesis, is energy burned through day-to-day activities, aside from intentional exercise. For example, things like housework, getting up and stretching throughout the day, or even fidgeting, would count as NEAT.[9]

Lastly, the biggest contributor to TDEE, accounting for 50-65% of total energy expenditure, is the basal metabolism, which is the energy used to maintain life at a complete rest. This is often quantified by measuring the BMR (basal metabolic rate) or RMR (resting metabolic rate).[1]

BMR and RMR are often used interchangeably, but there is a small difference (up to 10%). BMR is measured in a lab setting via indirect calorimetry, where the individual has slept overnight in the lab and their values can be measured first thing in the morning.

On the other hand, RMR is also measured in a lab, but the individual did not stay overnight and has thus awoken and traveled to the lab setting for the testing. Ultimately, this means BMR will be slightly more accurate as it's slightly more controlled.

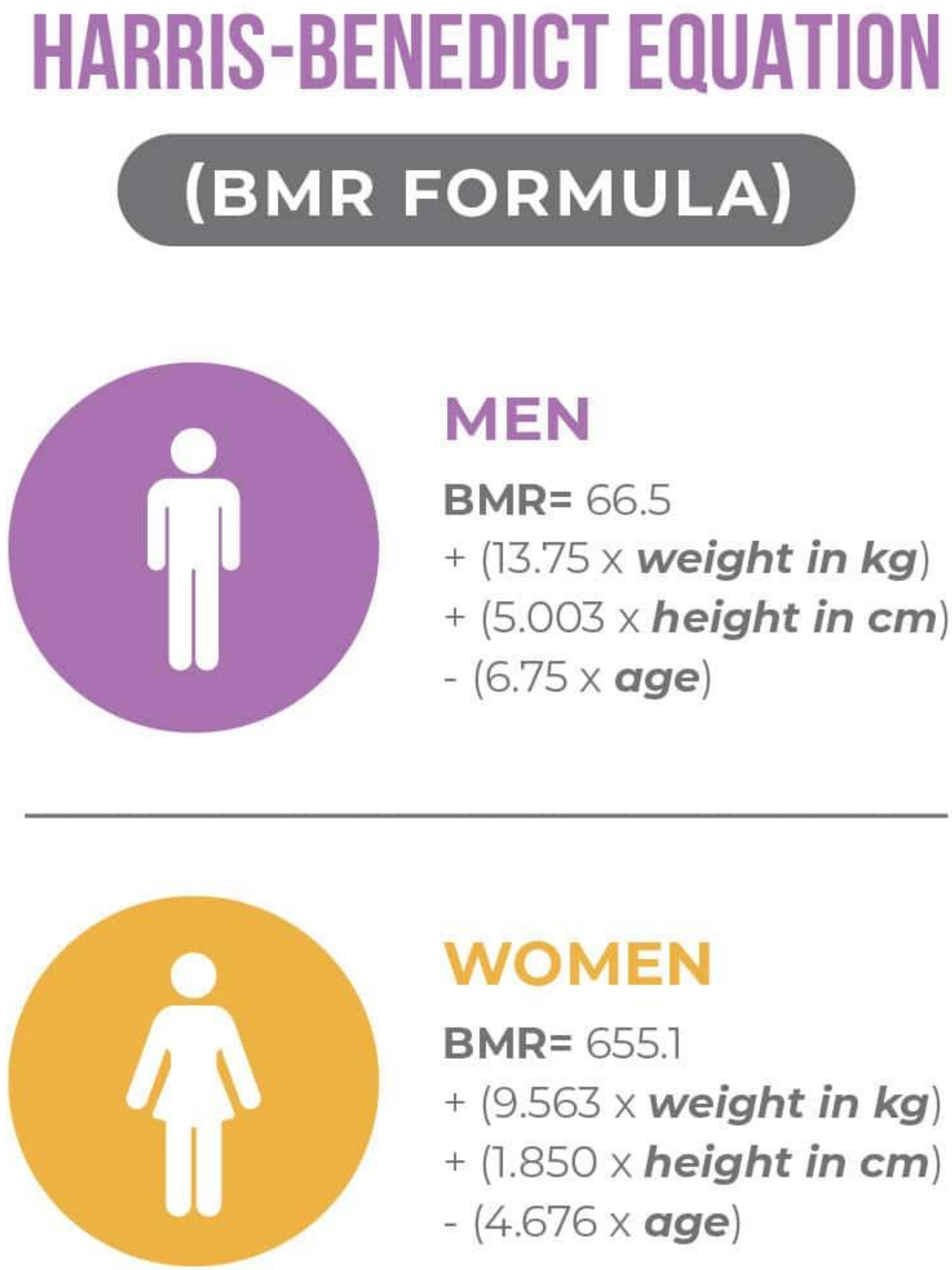
Such differences are rather small and what's more, BMR/RMR can change from day to day, depending on several factors like stressors, the use of caffeine, or the presence of a fever.[1] It can also be increased or decreased over time by changes in lifestyle factors.

While it's possible to measure BMR or RMR in a laboratory setting, this is not easily accessible for most individuals. Alternatively, several calculations have been developed to provide estimations.

Moving forward, this chapter will simply use the term BMR when discussing these calculations.

Calculations

There are many calculations that can be used to estimate BMR, but the Harris-Benedict equation, which considers an individual's gender, height, and weight, is commonly used.[10]



The result of these equations will be an estimate of an individual's BMR.

From there, the activity level of that individual needs to be considered. To factor this in, the next step will be to multiply the result from the equation above by the appropriate activity factor below:

Energy Expenditure Calculations via BMR

Activity level	BMR multiplied by:
Little to no exercise	1.2
Light exercise (1-3 days per week)	1.375
Moderate exercise (3-5 days per week)	1.55
Heavy exercise (6-7 days per week)	1.725
Very heavy exercise (twice per day, daily)	1.9

After multiplying the BMR by the activity factor, the result is an individual's TDEE, or the estimated number of calories they need to consume daily to maintain their body weight at their current activity levels.

While these calculations are used when indirect calorimetry is not available or accessible, it's important to note that they are not 100% accurate.[10] Increasing TDEE will likely be a goal of many personal training clients, particularly those looking to lose weight.

As a reminder, weight loss is typically observed when a negative energy balance is achieved, meaning the energy intake is less than the energy expenditure. Therefore, increasing TDEE would help promote a negative energy balance and ultimately, weight loss.

The most obvious method of increasing TDEE is to increase the amount of physical activity. This can be done through NEAT, or increasing overall movements throughout the day, as well as formal, structured exercise like sessions with a personal trainer or going for a bike ride or walk.

Another approach to increasing TDEE might be considering a diet higher in protein, as protein has a higher TEF than carbohydrates or fats. However, while this may lead to modest increases in TDEE, it's unlikely to be substantial.[7, 8] Lastly, research suggests that an increase in lean body mass may increase BMR and therefore TDEE, so promoting strength training and muscle building with clients is recommended.[11]

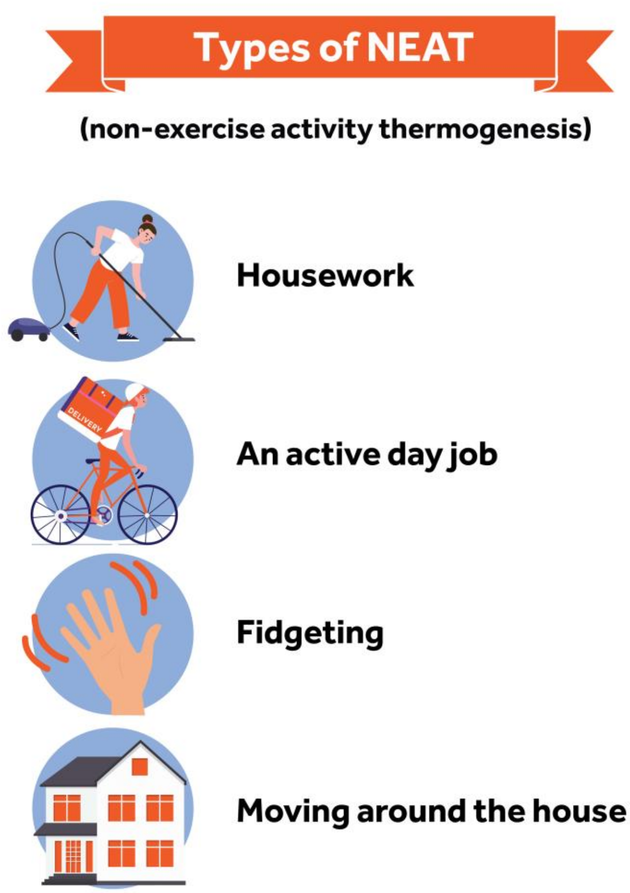
Calories

Changing caloric intake is an effective approach to changing body weight. As reviewed in earlier sections, a negative energy balance occurs when the calories eaten are fewer than the calories burned and thus results in weight loss and alternatively, a positive energy balance should promote weight gain.

A low-calorie diet typically involves anywhere from a 500-750 calorie deficit, meaning the difference between an individual's caloric intake and TDEE is 500-750 calories.[12]

For many, eating this many fewer calories each day is difficult, and a more modest deficit may be more realistic. While a smaller deficit may lead to slower weight loss results, it may be more effective overall as it's likely easier for an individual to commit to.[13]

Additional, increasing non-exercise activity thermogenesis (NEAT) by adding just a bit more movement to the day without additional exercise sessions can help individuals reach the target caloric deficit.



The success of a diet will rely heavily on an individual's adherence to the diet. Research suggests that keeping a food log and choosing a diet that fits the individual's food preferences are both effective strategies for improving adherence.[13]

Still, while there are many different approaches to weight loss, some of which will be reviewed in a later section, research has found that caloric intake is the most important factor.[12]

The same principles can be applied for an individual looking to gain weight, though the focus should shift to a caloric surplus.

It is again important for the approach to diet to be realistic and sustainable to achieve success.

Macronutrients

Macronutrients are compounds found in food that provide the body with energy, in the form of calories. There are three macronutrients present in foods: carbohydrates, fat, and protein.

Each of these provide a certain number of calories per gram, ultimately contributing to the total calories consumed in one's dietary intake.

- One gram of carbohydrate contains 4 calories.
- One gram of protein contains 4 calories.
- One gram of fat contains 9 calories.

As fat contains more than twice the number of calories as carbohydrates and protein, it can be considered more calorie dense.

When it comes to weight loss, various approaches to macronutrients have been suggested. Research shows that caloric intake, along with sufficient protein intake, remains the most important factor.[12]

This means that whether a diet is lower in carbohydrates or fats does not determine the success of a diet. But, as adherence to a caloric deficit is a huge driving factor, an individual's preferences towards foods higher in carbohydrates or fats should be considered.

Additionally, though not technically considered a macronutrient, alcohol also provides energy in the form of calories.

- One gram of alcohol (ethanol) contains 7 calories.

This can be notable for individuals working on losing weight as calories coming from alcohol will contribute to overall caloric intake.

Calories in typical alcoholic drinks

Beverage	Serving Size	Total Calories	Calories from Alcohol
Beer	12 fluid ounces	153	96
Light Beer	12 fluid ounces	103	76
Red Wine	5 fluid ounces	125	108
Spirits	1 fluid ounce	82	82

The table above indicates that some alcoholic beverages, such as beer and wine, contain calories in addition to the calories from alcohol, while spirits are 100% alcohol.

This is because beer and wine contain carbohydrates in addition to alcohol.

Hydration and Fluid Needs

Proper hydration should be considered an essential part of a nutritional plan, particularly when exercise is involved.

Water is an essential part of healthy nutrition.

It's important for transporting nutrients throughout the body as well as carrying away waste products. It also helps to digest foods and regulate body temperature, especially during exercise.[15]

Athletes can lose large amounts of water through sweat during exercise. It's estimated 1.5 liters or more fluid can be lost during each hour of activity.

To prevent dehydration, which occurs when the body's output of water exceeds the input, individuals should focus on drinking plenty of fluids throughout the day, particularly before, during, and after exercise.[1]

Dehydration can lead to a rapid heartbeat, muscle weakness, low blood pressure, and other symptoms.

Recommendations for water intake can vary, but the Adequate Intake set by the DRI committee suggests 3 liters (about 13 cups) per day for adult men and 2.2 liters (about 9 cups) per day for adult women.[16]

It's important to note that total water here is used interchangeably with total fluid intake, meaning other liquids, such as milk or fruit juice, and even foods, thanks to their water content, can contribute to this number.

If an individual is particularly active, they will likely need to increase their amount of total water. To determine an exact amount of fluids needed, the hourly sweat rate can be calculated by weighing an individual before exercise and immediately after.

One pound of weight loss is approximately 2 cups of fluid.[1]

This means that an individual should focus on consuming a minimum of 2 cups of water (or about 16 ounces) per pound lost to sweat during exercise. Sufficient fluids should also be prioritized leading up to and during training.

Also, remember that sweat is not simply just water. It also contains electrolytes, which are electrically charged particles that maintain water balance inside and outside of cells, and, therefore, are essential to hydration.[15]

Sodium, potassium, calcium, and magnesium are all important electrolytes, but sodium tends to be lost in the greatest amounts through sweat.

For example, an average individual will lose up to 800mg of sodium in 2 pounds of sweat, but only 10mg of magnesium.[15]

Low levels of sodium can lead to something called hyponatremia, which can cause nausea, confusion, fatigue, and muscle weakness.

Thus, staying on top of both fluids and electrolytes is important for hydration.

Sports drinks containing carbohydrates as well as sodium can be particularly useful during exercise, especially for heavy sweaters or individuals exercising for extended periods of time, though they are not necessary for everyone. An approach to hydration before, during, and after exercise might look like this[1]:

- Throughout the day: 1 ounce of fluids per 10 pounds of body weight
- 2 hours before exercise: 0.6 ounces per 10 pounds of body weight
- During exercise: Sips of fluids to prevent dehydration
- After exercise: 16 ounces of fluids per each pound of body weight lost during exercise

Popular Diets

Ketogenic Diet

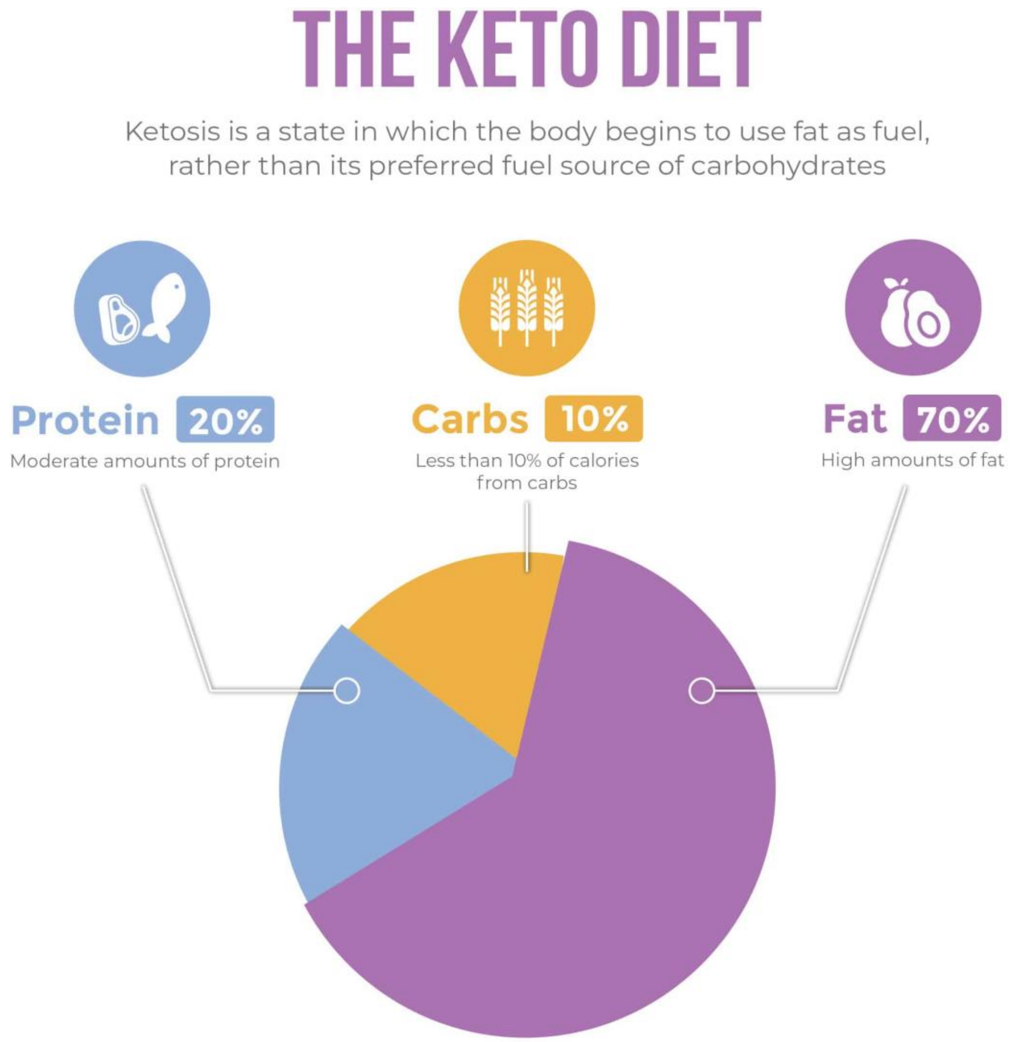
The ketogenic diet, also known as the keto diet, is a high fat, very low carbohydrate diet that aims to establish ketosis in the body. In the ketogenic diet, people typically consume less than 10% of total calories from carbohydrates or fewer than 50 grams of carbohydrates per day.

Ketosis is a state in which the body begins to use fat as fuel, rather than its preferred fuel source of carbohydrates.[12, 17] Originally used to help those suffering from epilepsy, the keto diet has more recently become popular for those looking to lose weight.[18]

Individuals following a keto diet generally see rather fast weight loss in the early stages of implementation. This is due to the diuretic effect of a low carbohydrate diet.[17]

Some research suggests that a keto diet may help decrease appetite and manage blood sugars and insulin levels.[12, 19] However, the research overall does not favor a low carb or low fat diet, but rather calorie restriction for successful weight loss.[12, 20]

While the keto diet may be effective for some, it may not be realistic or sustainable for others. Because the biggest factor is calories, this is an example where the individual's food preferences should be taken into consideration when considering a diet approach such as the keto diet.



Paleo Diet

The Paleolithic diet, or the paleo diet, is a hunter-gatherer style of eating that focuses on eliminating processed foods, which were not consumed by humans during the Paleolithic era.

The diet revolves around consuming foods like meat, vegetables, fruits, and nuts. It eliminates grains, dairy, and added sugars. Today, the Paleo diet has become extremely popular and there are several heavily marketed products throughout the fitness industry, claiming to be Paleo.

Some research suggests that the paleo diet may help improve blood lipids and blood pressure, but stronger, more conclusive research is still needed before these claims can be made.[12]

Ultimately, there is no conclusive research supporting the paleo diet over other types of diets for fat loss. It can also be rather restrictive and difficult to sustain for some.

Vegan Diet

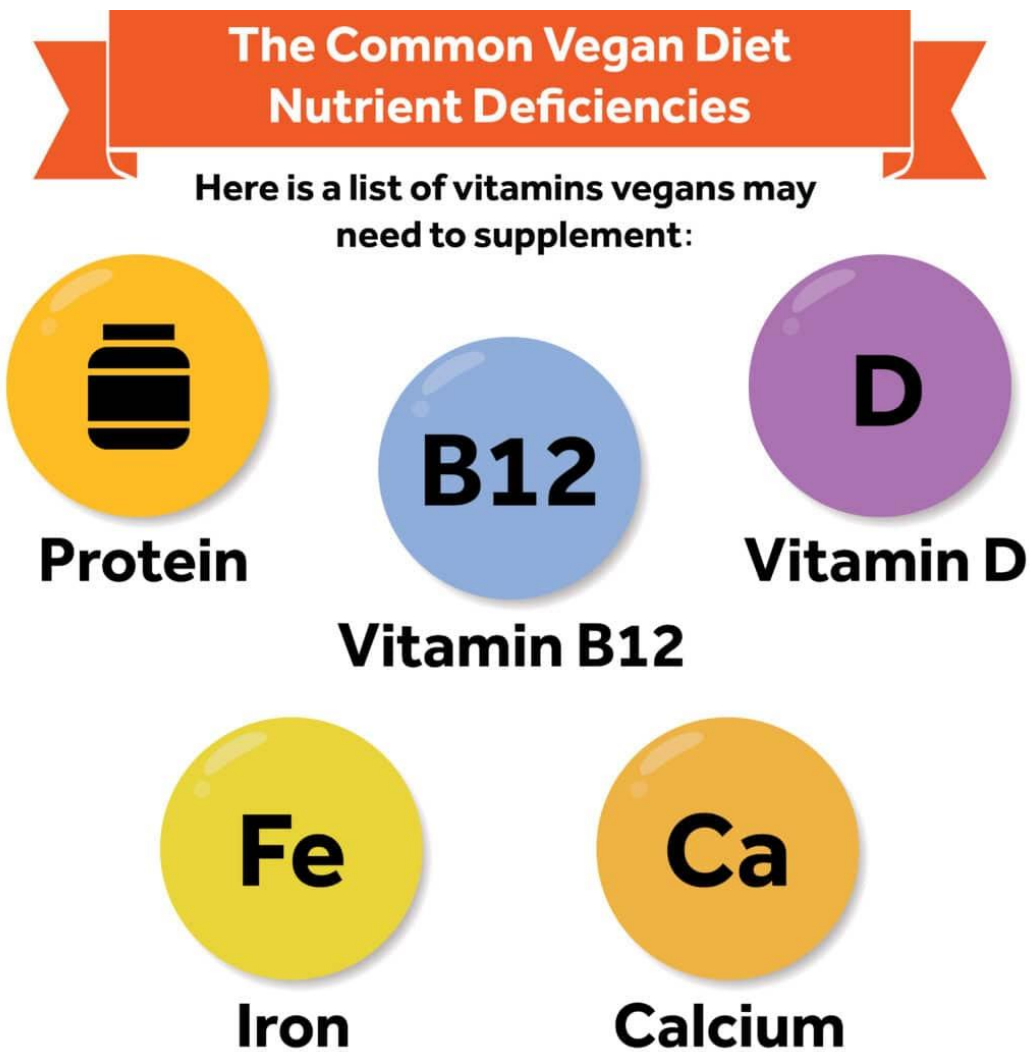
Vegan diets, or plant-based diets, eliminate all forms of animal products, including meats as well as foods derived from animals like dairy and eggs.

Some research does support a vegan diet for fat loss as its emphasis on plant-based foods may help improve insulin sensitivity, lower caloric intake, lower the risk of some chronic diseases, and ultimately promote weight loss.[21]

Some nutrients can become of concern on a vegan diet, including protein, vitamin B12, vitamin D, iron, and calcium.

It's possible to consume enough of these nutrients without eating animal products, but individuals must be educated in plant-based food sources to do so. Some may wish to use dietary supplements to cover any gaps in nutrition.[22]

As with other diets, a vegan diet could be difficult for some to follow, and individuals should focus on diets that fit their lifestyle and preferences.



Vegetarian Diet

Vegetarian diets eliminate meat, but often include things like dairy and eggs. This style of eating can be referred to as a lacto-ovo vegetarian diet. Some vegetarians prefer to follow a lacto-vegetarian or an ovo-vegetarian diet, meaning only meat and eggs are restricted, or only meat and dairy are restricted. Same may also consider themselves pescatarian, meaning they do not consume meat, but do eat fish and seafood.

Vegetarian diets have been found to offer various health benefits, including a reduced risk for type 2 diabetes, heart disease, and cancer. Some research supports vegetarian diets for fat loss, but more conclusive research is still needed on the topic.[12]

Plant-Based Diet

A plant-based diet can be similar to a vegetarian or vegan diet but with a bit more flexibility. It's a diet that emphasizes plant-based foods, but it may also include other whole foods, including animal products.[23]

Plant-based diets have been found to be beneficial in several ways, including lowering the risk of some chronic diseases, particularly heart disease, as they tend to be lower in saturated fats and higher in fiber.[24] As with other diets, a plant-based diet may be beneficial for fat loss, but the most important factor in success remains a caloric deficit.[12]

Intermittent Fasting

Intermittent fasting is a style of eating that involves a certain length of time of fasting, followed by an "eating window," during which all of one's calories are consumed for the day. There are several different approaches to intermittent fasting, some focusing on a 16 hour fast and 8 hour eating window, others recommending alternate day fasting, and more.[12]

Some potential benefits of intermittent fasting include improved insulin sensitivity and blood pressure.[25] There is also promising research that suggests intermittent fasting may be effective for weight loss, however the research overall remains inconclusive.[26]

As with many diets, this style of eating can be rather restrictive and difficult to sustain and fasting can cause feelings of dizziness, weakness, and headaches in some.[12]

As a reminder, a caloric deficit is essential for weight loss, and some individuals may find that following an intermittent fasting approach helps them to maintain this deficit, but others may find fasting for longer periods lead to periods of overeating.

Summary of Popular Diets

Weight loss does not depend on the specific type of diet but the adherence to a long-term calorie-deficit.[13]

There are many different popular approaches to dieting and fat loss. While some may have research supporting their benefits and some may even have research supporting their effectiveness for fat loss specifically, the conclusion remains that caloric intake is the biggest driving factor.[12, 27]

Additionally, adherence to a specific diet ultimately determines the effectiveness of that diet. Some approaches, such as keeping a food log, setting realistic goals, and a supportive environment, have been found to improve adherence.[13, 28]

Many of these diets work by creating a caloric deficit, which is necessary to promote weight loss. Individuals should consider their own preferences and lifestyle before choosing to follow a specific diet.

Healthy Eating Guidelines

General Healthy Eating Recommendations

Despite the limited scope of the personal trainer, some general healthy eating recommendations can still be made. Before providing any sort of recommendation, consider if it would fall into the scope of diagnosing, treating, or preventing a specific condition or prescribing specific dietary approaches.

If the recommendation does fall into any of the latter, it's best to refer the client to a registered dietitian.

Some general healthy eating recommendations for a client looking to lose weight or improve overall health might include:[12, 13, 16, 29]

- Drink plenty of water throughout the day (9-13 cups)
- Keep a food log
- Focus on high-fiber foods like vegetables, fruits, and whole grains to boost satiety
- Include a source of lean protein with each meal to increase satiety and support lean muscle mass
- Limit alcohol consumption
- Limit empty calories and ultra-processed foods
- Keep saturated fats and added sugars in moderation

Alternatively, if a client is interested in gaining weight, it's best to continue recommending the above healthy eating guidelines, but it's also important to encourage the following habits:

- Increase overall calories (in the form of carbohydrates, protein, and fat) by increasing portion sizes at meals and snacks
- Focus on protein to support muscle building and recovery

Alternatively, if a client is interested in gaining weight, it's best to continue recommending the above healthy eating guidelines, but it's also important to encourage the following habits:

- Increase overall calories (in the form of carbohydrates, protein, and fat) by increasing portion sizes at meals and snacks
- Focus on protein to support muscle building and recovery

Summary

The role of the personal trainer is centered around exercise and scope of practice must always be considered before offering any recommendations related to nutrition or other areas of expertise.

An individual's TDEE can be calculated using equations that consider their gender, height, weight, and activity levels. This can be used to determine a caloric deficit or surplus that can support a goal of weight loss or gain.

Hydration is an essential aspect of nutrition and fitness, particularly in heavy sweaters. Clients should be encouraged to drink 9-13 cups of water, and sometimes more depending on their sweat rate.

While various weight loss diets exist, research remains steady in support of caloric intake and adherence being the biggest driving factors in success. An individual should first consider their own preferences and habits before committing to a restrictive diet.

While personal trainers are limited in their ability to make nutritional recommendations, they can offer several sound healthy eating recommendations to those looking to improve overall health. Anything that involves diagnosing, treating, or prescribing specific dietary approaches should be referred to a registered dietitian.

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Macronutrients and Hydration

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Introduction

Macronutrients and water are necessary products that fuel the body's daily processes. This chapter defines what an essential nutrient is, how macronutrients function in the human body as well as hydration requirements and ways to make sure clients maintain the proper fluid intake.

Nutrients

Nutrients are defined as chemical structures found in foods that are necessary for human life and the growth, maintenance, and repair of body tissues.[1] The main nutritional constituents of food are proteins, fats, carbohydrates, vitamins, and minerals.

Essential Nutrients

The search for the nutrients considered essential for health began in the late 1950s. Scientist Alfred E. Harper first defined and summarized them in 1999.[1] The definition for essential nutrients includes several aspects.

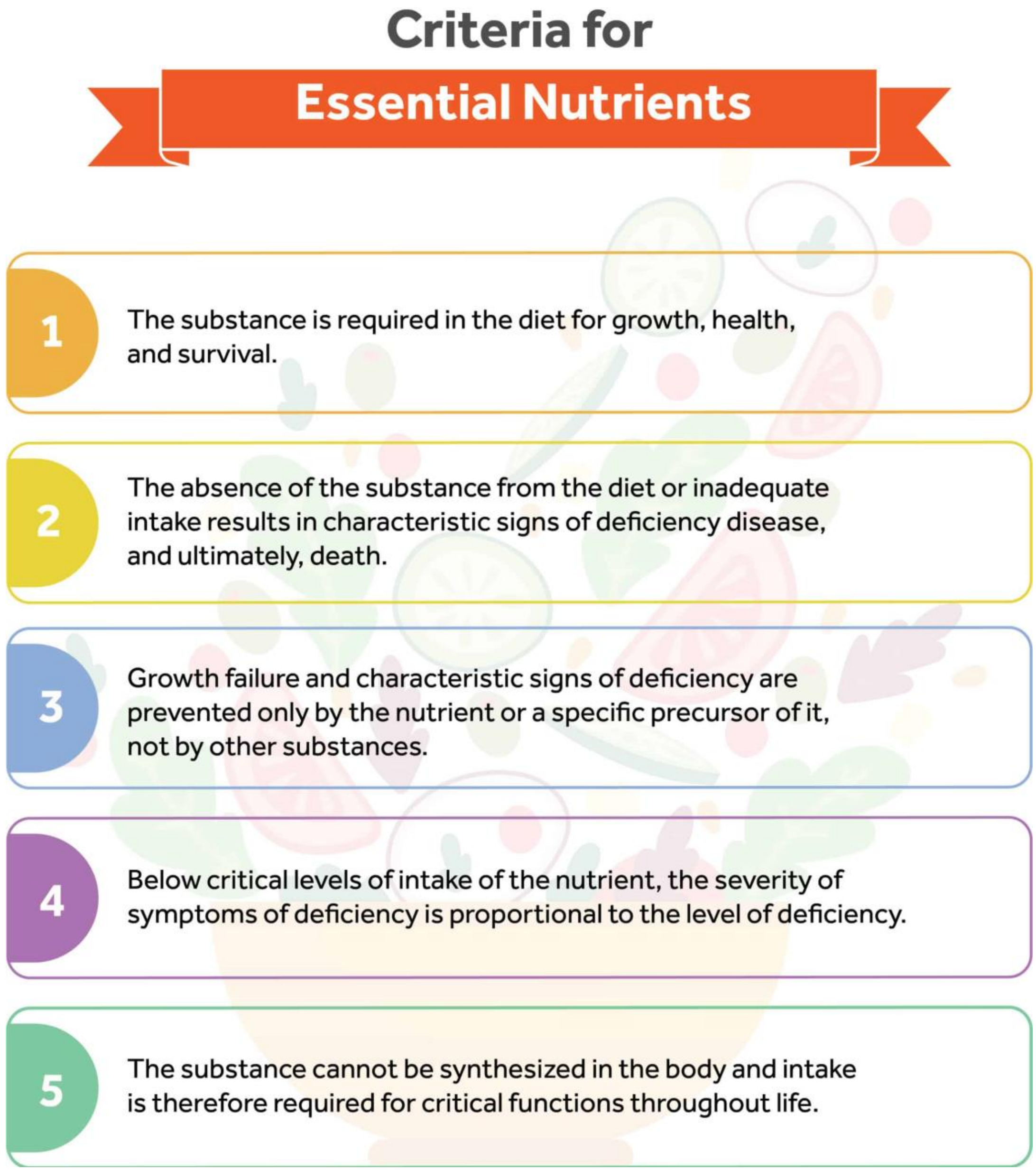
Firstly, the substance is required in the diet for growth, health, and survival. Without it, or without the proper amounts of it, human beings exhibit signs of deficiency, disease, and ultimately, death. For example, salt is required for life. It is essential for nerve and muscle functions and helps regulate regulate fluids in the body. It is critical.

Another part of the definition for essential nutrients includes the fact that growth failure and characteristic signs of deficiency are prevented only by the nutrient or a specific precursor of it, not by other substances. So only this substance or a precursor to it will prevent signs of deficiency. Arginine is a non-essential amino acid that has many profound effects, but can actually be synthesized from other nutrients rather than just arginine or a precusor.

The human body cannot simply synthesize essential nutrients from other substances.

Also, below critical levels of intake of an essential nutrient, growth response, and severity of signs of deficiency are always proportional to the amount consumed, meaning a larger deficiency will lead to further and further symptoms and issues.

Examples of essential nutrients include certain carbohydrates, protein, fats, certain vitamins, minerals, and water.



Conditionally Essential Nutrients

With increasing scientific knowledge of human nutrition, came the understanding that some nutrients are not essential to maintain life. Defined as conditionally essential or indispensable, nutrients are the substances that partly meet the criteria for essentiality yet are not required in the diet.[1] The only exception to the norm is specific populations that do not synthesize them in adequate amounts.

Non-Essential Nutrients

Non-essential nutrients are substances that cannot be synthesized by the human body but may be included in the diet given their significant effect on health, although the body can survive without them. Examples of non-essential nutrients include biotin, vitamin K, cholesterol, dietary fiber, certain amino acids, and fatty acids.

Macronutrients

Macronutrients are carbon compounds derived from food sources that provide the essential energy for growth, maintenance, metabolic functions, and survival. The three main sources of macronutrients include carbohydrates, proteins, and fats. Alcohol can be considered an alternative macronutrient because it is its source of energy but it is not essential for survival.

Energy Content and Structure of Macronutrients

Energy

Energy can be defined as the strength and vitality required for sustained physical or mental activity. The sun is the main source of energy for all living organisms and is primarily used by photosynthetic organisms such as plants, algae, and cyanobacteria to make carbon matter from carbon dioxide and water.[3] Human beings require the use of this energy for building metabolic substances and components that are essential for growth and survival.

The energy that food produces is directly measured by calorimetry. In chemistry and thermodynamics, calorimetry is the science that measures the amount of heat that is transferred by burning a sample of food mass. In biological systems energy in foods is measured in kilocalories (kcal) or kilojoules (kJ). One kilocalorie (equivalent to 4.184 kJ) is the amount of heat required to raise the temperature of 1 kg of water to 1°C at standard atmospheric pressure of 760 mm Hg.[4] To simplify the following formula, the field of nutrition uses kilocalories and calories interchangeably and defines 1 Kcal = 1,000 cal or 1 large calorie.

The three main macronutrients individually provide a relative energy content that can be measured by kilocalories per gram. Carbohydrates and proteins provide us with 4 kcal per gram and fats with 9 kcal per gram. Alcohol is not a nutrient but provides 7 kcal per gram as usable energy.

Certain nutrients require more energy to digest than others, which reduces the net energy supplied by the nutrient. Fiber, for example, requires significant energy to digest. As a carbohydrate, fiber technically has 4 calories per gram. However, the net digestion requirements result in roughly 2 calories acquired per gram. Overall, the net energy or caloric value of a food is the energy that is supplied to the body after each nutrient has been metabolized.

Carbohydrates

Functions

Carbohydrates are the most abundant organic compound in food and the major energy source for humans, supplying half or more of the total caloric intake for many.[5] Carbohydrates exist as large molecules in the cell walls of bacteria, plants, and the connective tissues of animals to maintain structure and protection.[6] The principal role of carbohydrates is to provide energy and regulate blood glucose and insulin metabolism.[7]

Carbohydrates also function as metabolic intermediates in the biosynthesis of fat and protein and participate in biological recognition and communication processes within cells.[7] Different metabolic states can signal the body to store carbohydrates until further energy is needed or break down the stores for energy use.

Certain types of carbohydrates also function to supply dietary fiber into the system and promote good digestive health. Carbohydrates are primarily found in fruits and vegetables, grains, legumes, commercially-prepared sweeteners, syrups, sugars, and baked goods.

Structure and Properties

Carbohydrates are structurally made from carbon (C), oxygen (O), and hydrogen (H) atoms. The general chemical structure for carbohydrates is $(CH_2O)_n$ where n is the number of carbons in the molecule.[8]

Carbohydrates can be classified into two major classes: simple carbohydrates and complex carbohydrates depending on the number of sugar molecules in the structure. Simple carbohydrates include monosaccharides (1 single sugar unit), and disaccharides (<2 sugar units). Complex carbohydrates include oligosaccharides (3–10 sugar units) and polysaccharides (>10 sugar units).

Simple Carbohydrates

Monosaccharides, also termed simple sugars, are the basic units from which all carbohydrates are built. Monosaccharides differ from complex carbohydrates in that they are colorless crystalline structures with a sweet taste, solid at room temperature, and soluble in water.[8] Simple carbohydrates are classified using numerical prefixes (tri-, tetra-, penta-…) according to the number of carbon atoms.8 Following this rule, monosaccharides with three carbons are called trioses, those with four are carbons tetroses, those with five are carbons pentoses, and so forth. The most abundant monosaccharide in nature and most important nutritionally is glucose, a six-carbon sugar.[8] Other common monosaccharides found in foods include fructose and galactose.

Disaccharides are composed of two monosaccharides covalently linked by glycosidic bonds. Disaccharides can be readily broken down (hydrolyzed) or reduced to their constituent monosaccharides by acidic or enzymatic reactions.[8] Similar to monosaccharides, disaccharides are also colorless crystallized structures with a solid appearance.[8] The most significant structures in this group are sucrose, lactose, and maltose as summarized below:

Sucrose

Also known as table sugar, sucrose is a sugar present in fruits and vegetables, predominantly sugarcane. Sucrose consists of one glucose and one fructose molecule and is represented by the molecular formula $C_{12}H_{22}O_{11}$. Sucrose is characterized by being highly soluble in water and sweeter than its constituent disaccharides.[8] The functional property of the former is partially influenced by fructose, the monosaccharide with the highest content of sugar. This is why sucrose is widely extracted to be used as a sweetening agent and to form syrups and nectars.

Lactose

Lactose is the only sugar that is biologically made in the body, particularly in the breast milk of lactating mammals. This disaccharide is present in dairy products like milk and cheese and commercially manufactured for pharmaceutical products and infant formulas. Consisting of one glucose and one galactose molecule, lactose is also represented as $C_{12}H_{22}O_{11}$, however, it is less sweet and soluble than sucrose.[8] Compared to milk from other mammals, human milk is considered unique in its high sugar content; it contains about 70 g/L lactose (7%) contributing to around 40% of the caloric value.[9]

Lactose intolerance is the deficiency or reduced activity of lactase enzymes in the small intestine that develops in some people after the consumption of milk or milk products. When lactose-containing products are consumed, the undigested lactose remains in the gut. As the bacteria in the large intestine ferment lactose, they produce hydrogen, methane, and carbon dioxide gas that causes bloating and abdominal pain. The presence of unabsorbed lactose and products of fermentation causes an increase in osmotic pressure, attracting water into the bowels, so water flows in and leads to diarrhea.

Maltose

Maltose is the most limiting sugar found in nature and is rarely consumed in the diet. Sources of maltose include germinated seeds of plants and grains that are kept in water for a long time.[8] Maltose is a disaccharide that is made of two glucose molecules and also shares the same molecular formula as that of lactose and sucrose ($C_{12}H_{22}O_{11}$). Similar to its constituents, maltose is sweet and soluble in water.

Complex Carbohydrates

Oligosaccharides are carbohydrate polymers that link three to 10 simple sugars by glycosidic bonds. Oligosaccharides are not as abundant as disaccharides except for maltodextrins and raffinose.[8] Maltodextrins are used in many commercially prepared foods as thickeners, sweeteners, humectants, and corn syrup, whereas raffinose, also known as "flatulence sugar" is naturally found in legumes and can lead to excessive flatulence as a result of gut bacteria fermentation.[10]

Polysaccharides are carbohydrate polymers composed of over 10 sugar units that exist in linear or branched formations. The properties of polysaccharides depend on their chemical and conformational structures. In general, highly branched polysaccharides are water soluble and form relatively nonviscous solutions, whereas linear polysaccharides tend to be insoluble in water and form viscous solutions.[8]

Polysaccharides exist as starch, glycogen, cellulose, and hemicellulose and are classified based on how readily digestible they are in the human body. The major digestible polysaccharides are starch, stored mainly in plant cells, and glycogen, stored solely in animal tissues, particularly in the liver and muscle.[8] Plants also synthesize polysaccharides that are non-digestible in the human gut such as cellulose, hemicellulose, and pectin.

Protein

Functions

Proteins are the most abundant macronutrient in the body that virtually exists in every cell, with over 40% of body protein found in skeletal muscle, over 25% found in body organs, and the rest found mostly in the skin and blood.[8] Proteins are virtually involved in every process that takes place in cells.

The principal functions of proteins are to act as transcription factors in genetic expression and to provide building blocks that aid in the growth, structure, and metabolic functions of tissues and organs in the body.[7] More specifically, proteins can act as energy substrates in periods of starvation or as messengers in storing proteins, forming enzymes, hormones, receptors, signaling proteins, and antibodies.[7] Proteins are present in whole foods of both plant and animal origin and used in the food industry to provide structure, texture, and palatability to food products.

Amino Acid Classification

Amino acids are units of protein in their simplest form made of a central carbon (C) that bonds at least one amino group (-NH2), at least one carboxyl group (-COOH), and a side chain (R group). Amino acids can be classified based on structure, net charge, polarity, and essentiality. What makes protein functions unique is the R group, a side chain that can take on many different chemical forms and is configured from one of the 20 amino acids that every human body requires to function.[8]

In 1957, William C. Rose and his colleagues defined a system of categorizing amino acids based on essentiality.[11] Out of the hundreds of amino acids that the body can build, only nine amino acids are considered essential or indispensable.[11] In other words, essential amino acids cannot be synthesized by the body and therefore must be supplied by the diet. The following list identifies the amino acids that are essential from those that are not essential.[11]

Peptides and Proteins

Proteins are chains of over 50 amino acids that fold into three dimension configurations. Similar to carbohydrates, amino acids form chains of various lengths held together by amide bonds, and named after the number of molecules in the chain. A polypeptide is a single linear chain made of many amino acids, and an oligopeptide is a chain of 2-20 amino acids.[8]

The naming of oligopeptides uses a similar approach to monosaccharides by using numerical prefixes (di-, tri-, tetra-, penta-...) to determine the size of the polymer.[8] For example, two amino acid molecules can be covalently joined to yield a *dipeptide*, three amino acids can be joined to form a *tripeptide*, four amino acids can be linked to form a *tetrapeptide*, and so forth.[8]

Lipids

Functions

Lipids, also referred to as fats, account for 30% to 35% of total caloric intake for many.[5] The primary function of lipids is to store energy in the human body and form structural components of cellular membranes.[7] Other important functions of lipids include providing lubrication and conditioning for body surfaces, acting as signaling molecules of receptors, antigens, sensors, electrical insulators, biological detergents, and membrane anchors for proteins.[7]

Lipids can act as specialized pigments (retinal and carotene), cofactors (vitamin K), and precursors for hormones (vitamin D derivatives, sex hormones).[8] Dietary sources of lipids predominantly exist as triacylglycerols (TAGs) in butter, oils, meats, dairy products, nuts, seeds, and many processed foods. Fats are commercially used as a cooking medium, to increase the tenderness of baked goods, and add richness and flavor to meals.

Structure and Properties

Lipids are structurally composed of carbon (C), hydrogen (H), and oxygen (O), but unlike carbohydrates, they are insoluble in water. The capacity to classify lipids is limited to their solubility property given that the systematic organic chemical naming of lipid structures is dominated by trivial names.[8] Lipids can therefore be classified based on the products of synthesis and their structural and functional similarities.

Triacylglycerols (TAGs) are virtually the most abundant storage form of lipids in the adipose tissue and account for nearly 95% of dietary fat. The structure of TAGs is composed of a glycerol backbone to which three fatty acids are attached by ester bonds.[8] The three fatty acids can be **saturated (SFA)**, **monounsaturated (MUFA)**, **polyunsaturated (PUFA)**, or a combination.[8]

Fatty acids are single fat molecules composed of a soluble carboxylic acid head and an insoluble hydrocarbon acid chain tail. Fatty acids are classified according to the length of the hydrocarbon chains and their degree of saturation. Typically short-chain fatty acids chains have fewer than 6 carbon atoms, medium-chain fatty acids have 8 to 14 carbons, and long-chain fatty acids have more than 14 carbons.[8] Fatty acids can also be classified as unsaturated or saturated depending on the number of double bonds in the hydrocarbon chain.

Trans Fatty Acids are chains of fat characterized by trans geometric bonds between a double bond. The degree of bonding plays an important role in the structure and function of cell membranes. The more carbon-carbon cis double bonds a chain has, the more pronounced the bonding effect.[8] Trans fatty acids are mainly produced because of partial hydrogenation.[8] Partial hydrogenation is the process commonly used to make frying oils and commercial food products remain solid at room temperature. The role of trans fatty acids in the etiology of cardiovascular disease is well established in the literature, indicating the potential risks associated with the consumption of trans fatty acids in the human diet.[12]

Unsaturated Fatty Acids are chains of fat molecules with at least one double bond. The main property of these fats is their ability to stay liquid at room temperature based on their double bond configuration.[8] Unsaturated fats exist as monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). MUFAs such as oleic acid (C18:1, ω-9) are considered omega-9 fatty acids (C18:1, ω-9) and are not essential in the diet.[8]

Sources of MUFAs include vegetable oils like olive, avocado, canola, peanut, and sesame oil. PUFAs such as linoleic and linolenic acid are essential in the diet because the body cannot synthesize them. Linoleic acid (C18:2, ω-6) is an omega-6 fatty acid that primarily exists as arachidonic acid (ARA) and can become inflammatory if consumed in a high amount.

Food sources of omega-6s are corn, soybean, and safflower seed oils. Linolenic acid (C18:3, ω-3) is an omega-3 fatty acid that appears to play anti-inflammatory roles in the prevention and treatment of chronic diseases.[13,14] Chief among the omega-3 fatty acids are eicosapentaenoic acids (EPA), and docosahexaenoic acids (DHA), found in whole foods such as cold-water fatty fish, shellfish, and algae, respectively.

Phospholipids are composed of glycerol, phosphate, and the appropriate base, such as choline, and show similar solubility properties to fatty acids. Particularly, the soluble head group and insoluble fatty acyl chains allow phospholipids to form outer layer membranes, structural components of the brain and nervous tissue, membranes of body tissues, and lipoproteins.[8]

Phospholipids are classified based on their head group. The five major classes of phospholipids thus are phosphatidylcholine (PtdCho, also called lecithin), phosphatidylethanolamine (PtdEtn), phosphatidylserine (PtdSer), phosphatidylinositol (PtdIns), and phosphatidylglycerol.[8] Phospholipids are found in sources of whole foods such as eggs, organ meats, lean meats, fish, shellfish, cereal grains, and oil seeds.

Cholesterol is a derivative of plant sterols that frequently exist in foods and body tissues esterified to one fatty acid per molecule. Similar to phospholipids, cholesterol is a membrane component essential in brain and nervous tissue formation.[8]

The main function of cholesterol is to form bile acids, steroid hormones, and the precursor to vitamin D.[8] Cholesterol occurs naturally in foods of animal origin, mainly in liver and egg yolk, red meats, poultry, whole milk, and cheese. Dietary cholesterol, which was once thought to increase the risk of heart events, is no longer associated with heart disease, ischemic stroke, or hemorrhagic stroke, and in some cases, appears to improve lipoprotein particle profiles and HDL functionality.[15]

Functions of Macronutrients

Carbohydrates:

- Provide energy and regulate blood glucose and insulin metabolism.
- Intermediate in the biosynthesis of fat and protein and participate in biological recognition and communication processes within cells.
- Different metabolic states can signal the body to store carbohydrates until further energy is needed or break down the stores for energy use.
- Certain types of carbohydrates function to supply dietary fiber into the system and promote good digestive health.

Primarily found in: fruits and vegetables, grains, legumes, commercially-prepared sweeteners, syrups, sugars, and baked goods.

Protein:

- Act as transcription factors in genetic expression and provide building blocks that aid in the growth, structure, and metabolic functions of tissues and organs in the body.
- Proteins can act as energy substrates in periods of starvation or as messengers in storing proteins, forming enzymes, hormones, receptors, signaling proteins, and antibodies.

Primarily found in: whole foods of animal origin, and certain plant sources, commonly used in the food industry to provide structure, texture, and palatability to food products.

Lipids (Fat)

- Stores energy in the human body and forms structural components of cellular membranes.
- Provides lubrication and conditioning for body surfaces, acting as signaling molecules of receptors, antigens, sensors, electrical insulators, biological detergents, and membrane anchors for proteins.
- Can act as specialized pigments (retinal and carotene), cofactors (vitamin K), and precursors for hormones (vitamin D derivatives, sex hormones).

Primarily found in: butter, oils, meats, dairy products, nuts, seeds, and many processed foods.

The Gastrointestinal Tract

The gastrointestinal tract (GIT) or gastrointestinal system is the tubular structure that extends from the mouth to the anus. The GI system includes the oral cavity, pharynx, esophagus, stomach, small intestine, large intestine, and rectum, as well as accessory organs (salivary glands, pancreas, liver, and gallbladder) that provide essential secretions. The main functions of the GI are (1) digestion of carbohydrates, proteins, and fats from dietary sources, (2) absorption of fluids, micronutrients, and trace elements, (3) and providing immune protection against pathogens.[16]

Digestion, Absorption, and Excretion

Digestion

Digestion encompasses all the processes that result in the breakdown of macronutrients into smaller units. Digestion is assisted by mechanical (physical) and enzymatic (chemical) processes. Mechanical digestion includes chewing, mixing of food with secretions from the GIT, and contractility of the stomach and the intestines to allow passage and breakdown of the food.

The process of digestion and absorption of macronutrients begins in the mouth. The mechanical forces of the oral cavity cut and grind food and mix it with saliva to form a food bolus.[16] The main role of saliva is to initiate the digestion of carbohydrates and fat, neutralize acids in the mouth, and assist in swallowing food.

Carbohydrates and fats are the only macronutrients that are initially digested in this site, with the aid of salivary amylase and salivary lipase, respectively. From the mouth, the food bolus is swallowed by passing from the pharynx into the esophagus. Swallowing is a voluntary reflex regulated by the brain.[16]

Once the bolus enters the stomach, the smooth muscles of the stomach, the gastric acid juices, mucosa, and enzymes facilitate the transformation of the bolus into a chyme.[16] The gastric juice is highly acidic and creates an acidic environment for carbohydrates, lipids, and protein to break down. Proteins are broken down into smaller peptides by pepsin, an enzyme that is activated by the hydrochloric acid in the gastric juice. Lipids containing triacylglycerols (TAGs) are hydrolyzed first into diglycerides and then fatty acids by the enzyme gastric lipase. Carbohydrates are further broken down by salivary amylase until it is inactivated by the low pH of gastric juice.

Absorption

Absorption is the movement of nutrients, including water and electrolytes across the mucosal lining of the GIT into the blood or the lymphatic system.[16] The main organ responsible for complete digestion and absorption is the small intestine, which accounts for specialized absorptive cells that increase the uptake of nutrients across the extracellular compartment.

Once the stomach has acidified the chyme, it enters the small intestine where it is completely absorbed. The small intestine is composed of three sections, the duodenum, the jejunum, and the ileum. Absorption is accomplished by structural components called villi and microvilli, hair-like extensions that project out of the lumen of the intestine and are made of absorptive cells to transport nutrients out into the blood.[16]

When predigested macronutrients enter the small intestine, the pancreas releases pancreatic juice and digestive enzymes to neutralize the acidic chyme and break down the nutrients for absorption. Pancreatic enzymes are specialized according to each macronutrient and can digest approximately half of all ingested carbohydrates, half of all proteins, and almost all (80–90%) of ingested fat.[16]

Protein peptides are hydrolyzed into amino acids by a group of protein-based enzymes called proteases that include trypsinogen, chymotrypsinogen, procarboxypeptidase, proelastase, and collagenase.[16] Proteases are formed in the pancreas and must travel to the small intestine to complete digestion before they are absorbed.

Fat droplets are first hydrolyzed by bile salts before pancreatic enzymes complete the process. Bile salts are composed of bile, an alkaline solution made and secreted liver that mixes with electrolytes, pigments, and other substances to emulsify fat.[16] This step allows pancreatic lipases made in the pancreas to completely digest fat for absorption.

Digestion and absorption of disaccharides greatly depend on the availability of enzymes within the small intestine. Disaccharides first move into the duodenum and jejunum where lactase, sucrase, and maltase act upon each of their constituents.

Lactase cleaves a lactose molecule to yield one galactose and one glucose, sucrase hydrolyzes sucrose to yield one glucose and one fructose residue, and maltase hydrolyzes maltose to yield two glucose units. Once they reach the ileum, pancreatic amylase completes the final digestion before monosaccharides are absorbed.

Transport

Following absorption of the smaller constituents by the villi of the ileum, water-soluble nutrients such as amino acids and monosaccharides, water-soluble vitamins, and electrolytes move across the intestinal mucosa into the portal blood until reaching the liver. The products of fat digestion such as monoacylglycerols and long-chain fatty acids must become reesterified to water-soluble molecules before crossing the intestinal barrier. Fatty acids reform to TAGs and combine with cholesterol and phospholipids to form chylomicrons.

Chylomicrons consist of a lipid core made of hydrophobic chains of fat, and a shell made of phospholipid heads that can move through water.[16] Unlike water-soluble nutrients, fat-soluble nutrients travel from lymphatic vessels into blood vessels and directly into the heart without making a first pass through the liver.

Excretion

The undigested material that has not been absorbed in the small intestine must move out from the ileum into the large intestine. The primary functions of the colon are (1) absorption of water and electrolytes from the ingesta, (2) microbial fermentation of undigested polysaccharides and resistant protein, and (3) formation and storage of feces.[16] The formation of stool or feces begins with mixing neutralized chyme with mucus. Organic materials that the body can't further process are digested and fermented by bacteria in the colon, and the remaining water left is absorbed. Normal feces are roughly 70% to 75% water and 20% to 25% solids.[16]

Metabolism

Metabolism is the sum of chemical reactions, secretions, and changes that occur within cells of organ tissues to provide vital energy for the body.[16] The metabolic processes involved in the body include anabolic and catabolic pathways. Anabolism or anabolic reactions are the metabolic processes that involve the synthesis of macromolecules such as proteins, glycogen, various lipids, and nucleic acids which promote growth.

Catabolism or catabolic reactions are the metabolic processes involved in the breakdown of organic compounds to CO_2 and H_2O with the release and breakdown of energy. The three organ systems that metabolize nutrients for storage and energy are the liver, the skeletal muscle, the adipose tissue, and the brain.[16]

Carbohydrates

The metabolic fate of monosaccharides depends on the body's energy needs. In the fed state, glucose levels start to rise and signal insulin in the pancreas to absorb glucose into the cells. Under these conditions, most tissues (liver, skeletal muscle, adipose, brain, and red blood cells) will increase glucose uptake, oxidation of glucose into energy, and storage for later use.[17]

The main catabolic pathways that take place in the fed state are glycolysis, tricarboxylic acid (TCA) cycle or citric acid cycle, and the pentose phosphate pathway (PPP).[17]

Glycolysis is the pathway that breaks down glucose into pyruvate.[17] Glycolysis has two fates depending on the availability of oxygen. When oxygen is present (aerobic glycolysis), glucose makes pyruvate enter the mitochondria and be oxidized to acetyl-CoA, which will enter the TCA cycle.[17] When oxygen is limited or energy demands exceed oxygen supply, the cell relies on anaerobic glycolysis.

In this case, lactate or lactic acid is formed, but the energy produced through this process is much less than through aerobic oxidation and therefore less favorable.17 If lactic acid levels start to rise, the Cori cycle takes place, by releasing lactate from the tissue, transporting it to the liver, and converting it back to pyruvate.[17]

The TCA cycle, also known as the citric acid cycle or Krebs's cycle, is the pathway that takes place in the mitochondria to convert pyruvate into energy.[16] This can only take place in the presence of oxygen and acetyl-CoA, an intermediate breakdown product of carbohydrates, protein, and fat. This cycle produces 90% of the body's energy as ATP and results information of carbon dioxide (CO_2) and water (H_2O).[17]

Monosaccharides can also undergo anabolic pathways in the fed state. The most important pathway is glycogenesis. This process synthesizes single units of glucose into glycogen to serve as the main storage form of carbohydrates in the liver and skeletal muscle.[17] On the contrary, when the body is in the fasted state, it will decrease serum glucose levels by the actions of glucagon in the pancreas and utilize alternative fuels for energy.[17]

Glycogenolysis is the catabolic pathway that takes place in the fed state and forms glucose from glycogen stores to maintain blood glucose levels.[17]

Fat

The adipose tissue is the main site for fat metabolism and storage. In the fed state, glucose, as well as dietary fat and cholesterol (transported as chylomicrons), are taken up by the adipose tissue.[17] Dietary fat undergoes lipogenesis, an anabolic reaction that oxidizes glucose to glycerol and synthesizes them to triacylglycerols (TAGs).[17]

The liver can also synthesize fat but should never store fat. To prevent fat accumulation, the liver is equipped with lipotropic factors that promote the removal of fat from the liver].[16] During a fasting state, the signaling of hormones such as glucagon and growth hormone will stimulate the activation of lipolysis.[17] Lipolysis is a catabolic pathway that releases fatty acids from stored triacylglycerols and provides an oxidizable substrate for the skeletal muscle and liver.[17]

Protein

Protein metabolism mainly takes place in the liver. Since protein can't be stored in the body, once protein needs are met, any protein excess is used to make fat and fat storage deposits, and energy, or is removed by the kidneys in the urine.

In the fed state, protein synthesis is the main anabolic reaction that takes place in the ribosomes of liver cells to form proteins from amino acids.[17] This pathway involves a complex interplay of many macromolecules including ribosomes, messenger RNA (mRNA), transfer RNA (tRNA), the genetic code, and protein factors.[16]

Muscle protein synthesis (MPS) is the metabolic process that describes the incorporation of amino acids into bound skeletal muscle proteins.[18] Muscle proteins can be classified into contractile myofibrillar proteins (i.e., myosin, actin, tropomyosin, troponin) and energy-producing mitochondrial proteins.[18]

Depending on diet and translation needs, excess amino acids will undergo amino acid catabolism where amino acids split off the nitrogen groups to form free ammonia. Given that ammonia in the blood can be toxic, it must be converted into urea through the urea cycle, to safely remove it from the blood and into the kidneys.[17] Some of it can be converted into purines, and some are used to make the nonessential amino acids through transamination. Excess amino acids are not stored, rather the deaminated carbon skeletons can be stored as glycogen or fat.[17]

In the fasted state, the main anabolic pathways that take place are gluconeogenesis and ketogenesis in the liver. Gluconeogenesis is an anabolic process that synthesizes glucose from lactate, amino acids, or glycerol. The glucose produced is released into the bloodstream to maintain blood glucose and provide energy for the brain and red blood cells (RBC).[17]

Ketogenesis is the biochemical process through which organisms produce ketone bodies by breaking down mostly ketogenic amino acids and fatty acids to serve as energy supply for certain organs, particularly the brain, heart, and skeletal muscle.[17] Ketogenesis and gluconeogenesis are similar in that they are both chemical processes that provide energy to the body when not enough carbohydrate is present in the diet. However, ketogenesis differs in that it produces ketones to be used as fuel, rather than glucose.[17]

Macronutrient Content in Foods

Carbohydrates

Carbohydrate is an umbrella term that encompasses sugar, fruits, vegetables, fibers, and legumes. Complex carbohydrates (oligosaccharides or polysaccharides) are generally preferred over simple carbohydrates because they take longer to digest and have a more gradual effect on the increase in blood sugar, whereas simple carbohydrates (monosaccharides) can rapidly raise blood glucose levels upon digestion. In some cases quick digesting carbohydrates are needed, but in most scenarios, slower carbohydrates are preferable, due to longer levels of energy.

The individual effects of food on blood sugar can be measured by the glycemic index scale that ranks carbohydrates from 0 to 100 based on how rapidly the rise in blood glucose occurs upon consumption.[19] The following lists food items as poor or beneficial sources of carbohydrates in terms of slow digestion.

Poor carbohydrates (quick digesting):

- Fruit juice
- White bread
- Crackers and crisp bread
- Breakfast cereals
- Processed grains and pasta
- Sodas
- Sweets
- Convenience foods
- Sweetened dairy products

Beneficial carbohydrates (slow digesting):

- Fruits (all whole fruits)
- Non-starchy vegetables (spinach, broccoli, kale, cauliflower)
- Starchy vegetables (potatoes, sweet potatoes, carrots, beets, peas, corn, pumpkin, rutabaga)
- Unrefined whole grains (brown rice, whole wheat, oatmeal, muesli, whole grain pasta)
- Legumes (lentils, chickpeas, soybeans, baked beans, cannellini beans, kidney beans)
- Dairy products (non-fat, 1% milk, 2% milk, low-fat yogurts)

Protein

Complete protein sources are generally of animal origin except for some plant-based foods. Complete protein refers to foods that contain all the essential amino acids required in the diet.[20] Despite this, it would be wrong to assume that animal-based foods provide more protein than plant-based ones.[20] Not all plant foods are low in the same amino acids, so eating a variety of plant-based foods can provide all nine of the essentials.[20] Complete animal proteins include eggs, dairy, meat, and seafood; whereas complete plant-based foods mainly include soy.

High protein foods

- Meat (7g protein/oz)
- Fish and shellfish (7g protein/oz)
- Eggs (7g protein/oz)
- Cow's Milk (8g protein/cup)
- Goat's Milk (9g protein/cup)
- Soy Milk (7-8 g protein/cup)
- Plain yogurt (6-7g protein/1/2 cup)
- Greek yogurt: (11-15g protein/1/2 cup)
- Cheese (7g protein/1oz)
- Nut butter (8g protein/2 Tbsp)
- Tofu (4.6 g protein/oz)
- Lentils, cooked (10g protein/1/2 cup)
- Chickpeas, cooked (8g protein/1/2 cup)
- Quinoa, cooked (4g protein/1/2 cup)
- Teff, cooked (5g protein/1/2 cup)
- Chia seeds (5g protein/oz)

Fats

Fats and oils are naturally found in both plants and animal foods, and, most recently, commercially prepared as hydrogenated oils. Oils are classified by their stability at room temperature and essentiality.

Particularly trans fats, saturated fats, and some omega-6 vegetable oils have been shown to promote inflammation, whereas a diet high in monounsaturated fat and essential omega-3 fats have been shown to inhibit and reduce inflammation by interfering with pro-inflammatory compounds naturally made by the body.[13, 14] Diets supplemented with omega-3 fats have been shown to reduce post-exercise delayed-onset muscle soreness and inflammation and promote healing.[21]

Essential Fats

- Seeds
- Nuts
- Legumes
- Fish and shellfish
- Vegetable oils

Non-essential Fats

- Tropical oils
- Vegetable oils
- Peanut oil
- Butters and solid fats
- Red meats
- Dairy products
- Snacks

Macronutrient Recommendations for Fitness Goals

Dietary Intake Guides

The Recommended Dietary Allowance (RDA), first established in 1941 by the Food and Nutrition Board of the Institute of Medicine, defined the average daily amount of nutrients to meet the needs of most healthy people.[5] With changes to the food supply and needs of the general population, the RDAs were adapted into a framework of nutrient recommendations called dietary reference intakes (DRIs). Included in the DRIs are RDAs, as well as guidance on safe upper limits (ULs) of vitamins and minerals.

1-based guidelines revised and published every five years by the National Academy of Sciences Food and Nutrition Board of the Institute of Medicine (IOM) in conjunction with the U.S. Department of Agriculture.[22] The first ever published guidelines were a federal government response to the increasing national concern for the rise in nutrition-related chronic diseases.[19]

Today, the DGAs are used by accredited nutrition professionals to assist the public in consuming a healthy diet.[22] For other health and community professionals, including the government, the information in the DGA can be incorporated into community programs and used to create educational materials for consumers and health initiatives.[22]

In 2011 the MyPlate guidelines from the USDA replaced the previous MyPyramid diagram.[23] The MyPlate is designed for the general population and serves as a food guidance system to choose foods from within and across food groups to meet nutrient needs.[23] The amounts vary based on a person's gender and age.

Generally, MyPlate suggests that adults consume the following each day: at least 2 cups of fruits, 2 and 1⁄2 cups of vegetables, a minimum of 3 oz of whole grains, at least 1 and 1⁄2 cups of beans and peas weekly, 5 to 6.5 oz of protein, and 3 cups of dairy.

Macronutrient Requirements

Carbohydrates

According to the RDAs, healthy adult diets should consume 130 grams of carbohydrates per day to maintain the most essential functionalities of the brain.[5] The Acceptable Macronutrient Distribution Range (AMDR) suggests including 45 to 65% of daily calories in the form of carbohydrates, or 225 and 325 grams of carbohydrates based on a daily 2,000 calorie diet.[5]

Recommendations for daily carbohydrate intake in the athlete population vary by gender, age, body mass, and training needs. A carbohydrate intake of 5 to 7 g/kg/day can meet the general training requirements, an intake of 7 to 10 g/kg/day of carbohydrates will likely suffice for endurance athletes, and for elite athletes training 5 to 6 hours a day, 12 g/kg/day or a range of 420 to 720 g of carbohydrates are appropriate.[24]

Carbohydrate intake will also vary greatly depending on the training modality. When glycogen stores drop to critically low levels, the athlete must either stop exercising or drastically reduce the pace. If athletes experience glycogen depletion after exercise, a carbohydrate intake of 1.5 g/kg body weight during the first 30 minutes and again every 2 hours for 4 to 6 hours is recommended.[19]

As a general recommendation, athletes should consume a mixed meal after strenuous training that provides a balance of all three macronutrients to help build and repair muscle tissue. If the goal of the client is solely to gain a healthy weight of lean muscle tissue, an additional 500 to 1,000 calories per day can be added in addition to strength training.[19]

Protein

Protein requirements greatly vary depending on the age, body size, and physiological state, as well as the level of energy intake of each individual. The RDA of protein for adults (men and women aged 19 years and older) is set at 0.8 grams of protein per kilogram of body weight to maintain basic function.[5] The AMDR for protein is 10 to 35% of calories for adults or about 50 to 175 grams per day for people consuming 2,000 calories per day.[5]

The athletic population will have an increased need for protein intake depending on the training modality that the individual is engaged in. For endurance athletes, nitrogen balance studies in men suggest a protein recommendation of 1.2g/kg per day.[25]

If resistance training is the main modality, protein requirements are higher than endurance exercise, and it has been recommended that experienced male bodybuilders and strength athletes consume 1.6 to 1.7g/kg/day to allow for the accumulation and maintenance of lean tissue.[26, 27] For athletes interested in muscle hypertrophy, it appears that neither the type nor the number of proteins matters if the day's total amount is within the recommended range for resistance-training athletes of 1.2 to 2 g/kg/day.[19]

Protein intake after training is essential to help build and repair muscle tissue. Research shows that a minimum of 30 g of high-quality protein at each meal that contains 2.5 g leucine per meal optimally stimulates protein synthesis, and when leucine and omega-3 fatty acid are supplemented there is a reduction in muscle loss for acutely injured athletes.[21]

Fats

The Food and Nutrition Board of the IOM has not established RDAs for fats.[5] The AMDR for fat is between 20 to 35% of total dietary calories for adults age 19 and older or about 44 to 77 grams of fat per day if consuming a 2,000-calorie diet.[5] The AMDRs recommend adjusting the number of calories coming from fat based on the type of fat.

It is recommended that monounsaturated fats represent 15% to 20% of total calories/day, polyunsaturated fat 5% to 10% of total calories/day, saturated fat less than 10% of total calories/day, cholesterol less than 300 mg/day, and completely zero trans fats.[5] The IOM also gives recommendations for the two essential fatty acids: linoleic acid (men, 14–17 g/d; women, 11-I2g/d) and linolenic acid (men, 1.6 g/d; women, I. I g/d).[5]

Fat is a macronutrient that should never be disregarded in the dietary pattern of athletes, since there is no performance difference with less than 15% of energy from fat, compared with 20% to 25% of energy from fat].[28] Fat is also essential in athletes' dietary intake as it provides energy, fat-soluble vitamins, and essential fatty acids.

Hydration Requirements and Strategies

Water Function

Water (H2O) is an essential nutrient that makes up the largest component of the body, accounting for about 73% of lean body mass in adults.[19] As a vital nutrient to both humans and plants, water functions to (1) dissolve nutrients, minerals, gasses, and enzymes, (2) regulate body temperature, (3) lubricate and moisten tissues, (3) transport nutrients and oxygen into cells and remove excess waste, (4) maintain blood volume and acid-base (pH) balance.[19]

Electrolytes

Within fluid systems in the body exist electrolytes, and electrically charged minerals that regulate fluid balance, movement, and distribution within other compartments. Electrolytes are responsible for (1) the maintenance of physiologic body functions, (2) cellular metabolism, (3) neuromuscular function, and (4) osmotic equilibrium.[19] The major extracellular electrolytes are sodium (Na+), calcium (Ca2+), chloride (Cl-), and bicarbonate (HCO3-). Potassium (K+), magnesium (Mg2+)., and phosphate $(PO_4)^{3-}$.[19]

Dehydration

Water is naturally lost throughout the day by the respiratory tract, skin, gastrointestinal tract, and kidneys. During physical exercise, the body increases the rate of sweat production leading to substantial water and electrolyte losses. If sweat water and electrolyte losses are not replaced then the individual will dehydrate during physical activity.

Dehydration refers to the loss of body water of 2% or more of body weight.[19] The typical symptoms of dehydration include extreme thirst, decreased urine output, secretion of concentrated urine, headaches, fatigue, muscle cramps, hypotension, and fever.[19]

The effects of body water loss ultimately alter the functionalities of the central nervous system, thermoregulatory system, cardiovascular system, and metabolic functions. Excessive dehydration can increase the risk for heat exhaustion[29, 30, 31] and heat stroke[32, 33, 34, 35] In addition, dehydration has been associated with reduced autonomic cardiac stability[36] altered intracranial volume,[37] and reduced cerebral blood flow velocity responses to orthostatic challenges.[38]

Water and Electrolyte Requirements

For an individual to maintain a water balance, the amount of water consumed must equal the amount lost from the body. The body can maintain a water balance by releasing and regulating hormones including antidiuretic hormone, aldosterone, angiotensin II, cortisone, norepinephrine, and epinephrine.[39]

The minimal amount of daily water to replace obligatory water losses from the respiratory tract, skin, feces, and urine is about 1.44 L. Calculations of daily water intake are also based on age group and exercise intensity.

Adults

According to the IOM, the general fluid requirements for adults are based on the formula 35 m/kg or 1mL/kcal of energy expenditure.[40] The IOM also recommends adequate intake (AI) values for total water at levels to prevent dehydration.[40] The AI for men aged 19+ is 3.7 liters each day, and 3 liters (13 cups) of which should be consumed as beverages.[40] The AI for women aged 19+ is 2.7 liters about 2.2 liters (9 cups) which should be consumed as beverages each day.[40]

Special attention must be given to this population given their increased risk for dehydration. The EFSA reviewed the literature and recommended an Adequate Intake (AI) of 2.0 L/day for women and 2.5 L/day for men of all ages (from a combination of drinking water, beverages, and food).[41]

Pregnancy and Lactation Pregnancy is also at risk for dehydration given the increased needs of the fetus, and the amniotic fluid. The water requirements for pregnant women are the same as in non-pregnant women plus an increase in proportion to the increase in energy intake (300 mL/day) is proposed. For lactating women, adequate water intakes of about 700 mL/day above the AIs of non-lactating women of the same age are derived.

Physical Activity

The level of physical activity of adults can also impact water requirements. The following guidelines can be used to assess fluid requirements before, during, and after physical activity:

Before an activity it is recommended to drink 17 to 20 oz of water 2 to 3 hours before the start of exercise or during warm-up to maintain normal plasma electrolyte levels.[40] Consumption of sodium in beverages (20-50 mEq/L) and/or small amounts of salted snacks or sodium-containing foods at meals helps to stimulate thirst and retain the consumed fluids.[40] On the contrary, hyperhydration can lower plasma sodium and increase the risk of dilutional hyponatremia.[40]

During activity it is suggested to drink 7-10 ounces of fluid every 10 to 20 minutes to prevent excessive dehydration.40 In prolonged exercise lasting greater than 3 hours, such as for marathon runners, a possible starting point is to drink ad libitum from 0.4 to 0.8 L/hr.[40]

Restoring hydration can be accomplished by drinking around 1.5 L/kg of body weight loss.[40] When possible, it is recommended that fluids are consumed over time (and with sufficient electrolytes) rather than being ingested in large boluses to maximize fluid retention .[42, 43]

Water replacement in the absence of supplemental sodium can lead to decreased plasma sodium concentrations.[19] When plasma sodium levels fall below 130 mEq/L, the individual can experience lethargy, confusion, seizures, or loss of consciousness.[40] Exercise-induced hyponatremia may result from fluid overloading during prolonged exercise over 4 hours.[40]

Hyponatremia is associated with individuals who drink plain water above their sweat losses or who are less physically conditioned and produce a saltier sweat.[40] Another important electrolyte, potassium, can decrease through sweat, but the loss of 32 to 48 mEq/day does not appear to be significant and is easily replaced by diet.[40]

Hot Weather Conditions

For individuals performing prolonged physical activity in hot weather, drinking fluid replacements or also known as electrolyte replacement is suggested. Beverages containing approximately 20-30 mEq/L of sodium (chloride as the anion), 2-5 mEq/L of potassium, and 5-10% carbohydrate are recommended.[44]

The sodium and potassium are to help replace sweat electrolyte losses, while sodium also helps to stimulate thirst, and carbohydrate provides energy.[44] These components also can be consumed by nonfluid sources such as gels, energy bars, and other foods.[44]

Summary

Macronutrients provide the essential energy for growth, maintenance, metabolic functions, and survival. Healthy adults should consume adequate amounts of protein, carbohydrates, and fat based on their weight and calorie requirements.

Water is a vital nutrient that dissolves nutrients, regulates temperature, lubricates tissues, transports important products across cells and removes excess waste, along with maintaining blood volume and acid-base balance in the body. Water and electrolytes are lost throughout the day and must be replenished, especially with added activity or warm weather conditions.

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Chapter 26

Micronutrients

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Introduction

Micronutrients are the compounds necessary to maintain the daily functions of the human body. These encompass organic and inorganic compounds such as vitamins and minerals.[1] There are nearly 30 of these nutrients considered to be essential because the body cannot manufacture them in sufficient amounts.

Thus, these micronutrients must be obtained from the diet in small amounts to maintain essential functions in the body, human development, disease prevention, and well-being.[1] Given the importance of micronutrients in health and fitness training, fitness professionals should have a working knowledge of the various key micronutrients required in a complete human diet.

Vitamins

Vitamins are organic compounds and are essential nutrients found in plants and animals that are only required in the diet in small amounts to maintain fundamental functions of the body.[2] Vitamins are categorized into two groups: water-soluble vitamins (the vitamin B group, C, folic acid, and biotin) and lipid-soluble vitamins (A, D, E, and K).[2]

The classification of vitamins is based on their solubility, and biochemical and physiological roles in digestion, absorption, and transport rather than chemical structures.[3] Another important distinction is that vitamins cannot be transformed into energy to meet metabolic demands nor used for structural purposes but can be easily broken down by heat, acid, or air. Hence vitamins are required in much smaller amounts than carbohydrates, proteins, and fats.[3]

Minerals

Minerals, or inorganic nutrients, are essential elements found in the soil and water and classified into macro and micro minerals. Macrominerals are composed of calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur.

The microelements may be considered in two groups: trace elements (iron, zinc, manganese, copper, and fluorine) and ultra-trace elements (selenium, molybdenum, iodine, chromium, boron, and cobalt).[3] Other minerals such as arsenic, nickel, vanadium, and silicon have proven some benefits in animal studies but have insufficient evidence to determine their essentiality or benefit for humans.

Role of Micronutrients in the Human Body

Micronutrients play a key role in metabolism, the maintenance of tissue function, and the prevention of critical illness. Optimal intakes of micronutrients are essential to all individuals, with observable clinical benefit in those who are severely depleted. Improper dosing of micronutrients carries its own risks and can be potentially harmful to those who exceed upper limit intakes of vitamins and minerals.[4]

The four main biochemical functions of micronutrients can be summarized below:

Cofactors

Cofactors are inorganic trace elements whose presence facilitates enzymatic reactions in metabolic processes.[4] For example, zinc is a cofactor for over 100 enzymes, whereas selenium is required in the form of selenocysteine within the enzyme glutathione peroxidase.[4]

Coenzymes

Coenzymes are defined as small, organic molecules that are required by an enzyme and that participate in the chemistry of catalysis.[3] In human biology, coenzymes are the vitamins whose presence is required to facilitate an enzymatic reaction.[4] For example, riboflavin and niacin are vitamins that participate in the electron transport chain by acting as intermediary elements to ensure the formation of energy, proteins, and nucleic acids.[4]

Transcription factors

Transcription factors are minerals that have a key role in genetic control.[4] For example, zinc "fingers" are transcription control factors that bind to DNA and regulate the transcription of receptors for steroid hormones and other factors.[4]

Antioxidants

Antioxidants are a class of micronutrients that aid in the removal and protection against mediators of systemic inflammation such as reactive oxygen species (ROS) or "free radicals."[4] Many vitamins have antioxidant properties.

For example tocopherol (Vitamin E) is a lipid-soluble antioxidant known to play an important role in scavenging free radicals that damage cells.[5] Wound healing and immune function also depend on adequate levels of vitamins and trace elements.[6]

The Four Main Biochemical Functions of Micronutrients

1. **Cofactors**
   Trace elements that are frequently an integral element of enzymatic reactions in metabolic processes
2. **Coenzymes**
   Small, organic molecules that are required by an enzyme and that participate in the chemistry of catalysis
3. **Transcription factors**
   Important factors that have a key role in genetic control
4. **Antioxidants**
   Vitamins that can undergo oxidative phosphorylation and aid in the removal and protection against mediators of systemic inflammation such as reactive oxygen species (ROS) or "free radicals."

Vitamins: Functions, Sources, Intake Guidelines, and Deficiencies

Fat-soluble Vitamins

Like any other fat, fat-soluble vitamins are absorbed into the lymphatic system before they can travel through the blood in association with protein carriers.[7] Fat-soluble vitamins can be stored within the liver or with other lipids in fatty tissues and tend to be susceptible to building up and potentially causing toxicity.[7] The requirements for fat solubles vary greatly, but periodic dosages (weeks or even months) are optimal requirements because the body can draw on its stores.[7]

Vitamin A

Vitamin A (Retinol, Retinoic acid) plays a vital role in vision and skin integrity and is involved in maintaining bone, teeth, nerves, and membrane integrity and functionality.[7, 8] The active form of vitamin A is present in organ meats, liver, fish oil, fortified milk, and foods such as enriched cereals. The precursor of vitamin A, beta-carotene, is naturally present in yellow and orange fruits, and dark leafy green vegetables.

When vitamin A supply runs low, night blindness (nyctalopia) can occur.[7, 8] This is a reversible process that can be corrected with adequate supplementation. If vitamin A deficiency is not corrected, it can lead to xerophthalmia, a more profound deficiency that results in permanent and irreversible blindness.[7, 8]

Populations at risk for vitamin A deficiency include those experiencing malnutrition, anorexia nervosa, burns, some forms of cancer, cystic fibrosis, and recent obstructions leading to surgery.[7,8]

Signs of vitamin A toxicity include headaches, weight loss, abdominal pain, blurred vision, muscle weakness, drowsiness, irritability, and peeling of skin.[7, 8] Vitamin A intake that exceeds the tolerable upper limit can lead to congenital birth defects in the eyes, skull, lungs, and heart.[7,8]

AI for infants is based on the amount of retinol found in human milk. RDA is 900 mg for men and 700 mg for women, adjusted for differences in average body size. UL is 3000 mg/d.[9] Vitamin A intake in pregnant women should be restricted if present in supplement form.

Vitamin D

Vitamin D (Calcitriol, D3) regulates calcium and phosphorus metabolism to maintain bone integrity.7, 8 The main sources of vitamin D are sunlight, egg yolks, fortified milk, and supplements, commonly referred to as Vitamin D_3 (cholecalciferol).

Plant sources also contain vitamin D in the D_2 form (ergocalciferol) and are equally as absorbable as Vitamin D_3. The precursor of this fat-soluble vitamin is cholesterol, which must travel to the liver to produce calcidiol, and finally to the kidneys where it becomes metabolically active as calcitriol.[7, 8]

The prevalence of vitamin D deficiency is especially high in the United States. The 2020-2025 Dietary Guidelines for Americans estimates that more than 90 percent of men and women older than age 19 years do not consume enough vitamin D.[9]

The most notable signs of vitamin D deficiency are bowed legs, rickets in children, and osteomalacia in adults.[7, 8] Susceptible individuals, particularly adolescents, people with dark skin, adult women, housebound elderly people, and many overweight and obese people are at high risk for insufficiency.[7, 8]

Vitamin D toxicity is rare, however, symptoms such as headache and nausea, upset stomach, bone fragility, and growth retardation have been reported in children receiving doses that exceed the tolerable upper intake.[7, 8] The AI for vitamin D recommended is 5-15 ug, UL is 100 mcg (4000 IU)/day, and RDA for individuals 19-50 years old is 600 IU (15 mcg). For those older than 70 years RDA is 800 IU (20 mcg).[11]

Vitamin E

Vitamin E (Tocopherol, Tocotrienol) acts as a lipid-soluble membrane antioxidant by scavenging free radicals and reducing inflammation.[7, 8] Vitamin E has important roles in muscular, vascular, nervous, and reproductive systems and acts as an anticoagulant and vitamin K antagonist.[7, 8] Vitamin E is naturally found in vegetable oils and derived products such as margarine and salad dressings, whereas animal fats have virtually none.

Vitamin E deficiency is rare, however, reported symptoms include changes in balance and coordination, muscle weakness, visual disturbances, prolonged blood coagulation, and hemolytic anemia.[7, 8]

In addition, the toxicity of vitamin E rarely occurs. Excessive doses of vitamin E can lead to dermatitis, fatigue, acne, vasodilation, hypoglycemia, increased requirement for vitamin K, abnormal coagulation and bleeding, and muscle damage.[7, 8]

Caution should be taken for individuals taking anticoagulant medication, as interactions with coagulant factors can occur and lead to uncontrolled bleeding and unwarranted brain hemorrhages.[12]

Intake guidelines for vitamin E increase with the use of PUFAs. The RDA for males and females ages 14 years and older is 15 mg/day (22 IU), UL is 1000 mg/day, and AI is 4-12 mg/day based on life stage and gender.[9]

Vitamin K

Vitamin K's primary function is to aid in blood clotting, calcium metabolism, and bone mineralization.[7, 8] Vitamin K is the only fat-soluble vitamin that is synthesized by bacteria in the gut to form prothrombin, a coagulation factor.[7, 8]

Vitamin K is mainly found in plant foods like dark green leafy and cruciferous vegetables. Smaller amounts can be found in animal foods such as fish, liver, meat, and eggs.

Vitamin K deficiency can cause bruising and abnormal bleeding due to its critical role in blood clotting.[7,8] Deficiency may also decrease bone density and as a result, increase the risk of osteoporosis.

For individuals taking anticoagulants, vitamin K toxicity can also block the effect of these therapeutic medications.[7,8] However, vitamin K toxicity is rare in healthy populations. Individuals who take large doses of vitamin A or E may also acquire a vitamin K deficiency due to the antagonist roles of the respective vitamins.

On the contrary, vitamin K toxicity is rare, but reports have been documented of prolonged bleeding time and breakage of the red blood cells leading to jaundice.[7,8]

Instances in which vitamin K is supplemented in doses higher than normal are during pre-surgery, or upon birth to prevent hemorrhagic diseases in newborns. Caution must be adverted to individuals taking anticoagulant medications.[7,8]

The RDA and AI are 120 mg/day for men and 90 mg/day for women. No UL has been established, but data is limited and one should not assume that high vitamin K consumption is harmless.[9]

Fat-Soluble Vitamins

Vitamin	Roles	Sources	Deficiency Risks	Intake Suggestions
Vitamin A	Plays a vital role in vision, skin-integrity	Organ meats, liver, fish oil, fortified milk, and enriched cereals	Low night blindness (nyctalopia) and xerophthalmia	900 mg/day for men 700 mg/day for women
Vitamin D	Regulates calcium and phosphorus metabolism to maintain bone integrity	Sunlight, egg yolk, fortified milk, and D supplements	Bowed legs, rickets in children, and osteomalacia in adults	600 IU/day (15 mcg) for individuals 19-50 years old 800 IU/day (20 mcg) for those older than 70 years
Vitamin E	Reduces inflammation, plays important role in muscular, vascular, nervous, and reproductive systems	Vegetable oils and derived products such as margarine and salad dressings	Changes in balance and coordination, muscle weakness, visual disturbances, prolonged blood coagulation, and hemolytic anemia	15 mg/day (22 IU) for individuals 14 and up
Vitamin K	Aids in blood clotting, calcium metabolism, and bone mineralization	Plant foods like dark green leafy and cruciferous vegetables	Bruising, abnormal bleeding, and risk of osteoporosis	120 mg/day for men 90 mg/day for women

Water-soluble Vitamins

Different from their constituent fat-soluble vitamins, water-soluble vitamins are absorbed directly into the blood and travel freely in the body through passive diffusion. Water-soluble vitamins cannot be stored, resulting in easy transport through the gut and excretion in the urine.[7]

Vitamin C

Vitamin C (Ascorbic acid) plays an important role in collagen formation and wound healing, tryptophan to serotonin conversion, folic acid metabolism, and iron absorption.[7, 8] Vitamin C can be found in citrus fruits, potatoes, papaya, and dark green and yellow vegetables.

The main signs of vitamin C deficiency are scurvy, poor wound healing, bleeding gums, and petechiae (brown spots on the skin).[7, 8] Vitamin C deficiency is especially high in individuals with severe trauma, surgical wounds, burns, cancer, chronic diarrhea, alcoholism, and Alzheimer's disease.[7, 8]

Excess vitamin C can occur and often manifests with GI distress and diarrhea.[7, 8] The RDA for vitamin C is 75 mg for women 19 years or older and teen boys. Pregnant women need 85 mg/day and lactating women need 120 mg/day. Teen girls need 65 mg/day, men 19 and older need 90 mg/day, and smokers need an extra 35 mg daily. The UL for vitamin C is 2000.[13]

Thiamin

Thiamin (Vitamin B1) is an essential coenzyme in the metabolism of pyruvate, the end product of glycolysis, and the master fuel input of energy in Krebs' cycle.[7, 8] Other key functions of thiamin are its role in cell respiration, RNA and DNA formation, protein catabolism, growth, appetite, normal muscle tone, and digestive and neurologic functioning.[7, 8] Sources of thiamin are found in organ and lean meats, pork, grains, wheat germ, eggs, dried legumes, seeds, and fortified cereals.

The main symptom of thiamin deficiency is beriberi, characterized by a lack of appetite, weakness, and swollen feet or legs.[7, 8] Other signs of deficiency include weight loss, mental confusion, and tachycardia.[7, 8]

Health conditions at risk include those suffering from malnutrition, severe alcoholism, cancer, celiac disease, cardiomyopathies, increased basal metabolic rate, and antibiotic overuse.[7, 8] Thiamin toxicity can lead to respiratory failure and death when doses surpass the tolerable upper intake, with noted symptoms of headache, convulsions, muscular weakness, cardiac arrhythmia, and allergic reactions.[7, 8]

The DRIs for thiamin include AIs for infants as found in human milk; RDAs are based on levels of energy intake with 1.2 mg/day for men and 1.1 mg/day for women.[9] No UL has been established.[9]

Riboflavin

Riboflavin (Vitamin B_2) is the main coenzyme in redox reactions of fatty acids and is involved in all macronutrients metabolic reactions to aid in cell respiration and energy formation.[7, 8]

Other roles of riboflavin are in the maintenance of mucous membranes, and the proper functioning of niacin and pyridoxine.[7, 8]

Sources of riboflavin are found in milk, yogurt, cheese, egg whites, liver, beef, chicken, fish, legumes, peanuts, enriched grains, and fortified cereals.

The most notable symptom of riboflavin deficiency is growth failure and cheilosis (fissures and scaling of lips). This leads to angular stomatitis (mouth sores), sore throat, and glossitis (magenta, swollen tongue).[7, 8]

Populations at risk for deficiency are those living in developing countries, those with severe alcoholism, cancers, drug use, and hormone imbalances.[7, 8] Riboflavin toxicity is extremely rare. The DRIs for riboflavin include AIs for infants and RDAs based on the amount required to maintain normal tissue reserves, RDA is 1.3 mg/day for men and 1.1 mg/day for women, and no UL has been established.[9]

Niacin

Niacin (Vitamin B_3, Nicotinic acid, Nicotinamide) serves as a coenzyme in the metabolism of carbohydrates, protein, and fat and has an important role in DNA repair and gene stability.[7, 8] The precursor of niacin is tryptophan, an essential amino acid, thus, niacin is mainly found in protein sources such as organ meats, poultry, saltwater fish, peanuts and legumes, enriched bread, and fortified cereals.

Signs of niacin deficiency include inflammation and swelling of the oral mucosa, esophagitis, diarrhea, headaches, insomnia, depression, anxiety, tremors, loss of motor function leading to numbness, and paresthesia in limbs.

Severe niacin deficiency can lead to pellagra, a disease characterized by dermatitis, diarrhea, dementia, and death if left untreated (the three Ds of pellagra).[7, 8]

Niacin toxicity is rare; however, cases reported include symptoms of hives, rash (“niacin flush”), excessive sweating, blurred vision, and liver damage. [7, 8] Intake for infants is established as AIs, RDA is 16 mg/day for men and 14 mg/day for women, and UL is 35 mg/day for men and women.[9]

Pantothenic Acid

Pantothenic Acid (Vitamin B_5) serves as a coenzyme in the energy synthesis of fatty acid metabolism. Pantothenic acid is available in all organic forms both in plant and animal tissues, the most important being organ meats, grains, legumes, egg yolks, milk, and sweet potatoes.

Deficiency of pantothenic acid is rare, but signs can include impaired lipid synthesis and energy production leading to nerve weakness and burning sensations in the feet, depression, fatigue, insomnia, and weakness. Toxicity is also rare, with excess B_5 causing mild intestinal distress or diarrhea.[7, 8] AI for adult men and women is 5 mg/day. UL is not established.[9]

Pyridoxine

Pyridoxine (Vitamin B_6) is a coenzyme in amino acid metabolism and is known for its role in gene expression and hemoglobin synthesis. Pyridoxine can be found in organ meats, fortified cereals, legumes, and nuts. Signs of pyridoxine deficiency are rare but may present as anemia, confusion, irritability, peripheral neuropathies, glossitis, and dermatitis. In addition, toxicity is relatively low, with symptoms reported as limited peripheral sensations, and muscle incoordination.[7, 8] The DRIs for vitamin B_6 include AIs for infants. Infants need three times as much vitamin B_6 as adults. RDA is 1.3–1.7 mg/day for men and 1.3–1.5 mg/day for women. The UL is established at 100 mg/day for adult men and women.[9]

Biotin

Biotin (Vitamin B_7) is a coenzyme in fatty acid synthesis, and carbohydrate metabolism, and plays an important role in converting pyruvic acid to oxaloacetate to initiate the Krebs cycle.[7, 8] Sources of biotin are present in organ meats, pork, egg yolk, cereals, legumes, and nuts.

Similar to vitamin K, biotin is the only water-soluble vitamin that is synthesized by gut bacteria. The deficiency of biotin is identified by signs of inflammation on the skin and lips, dermatitis, alopecia, paralysis, depression, nausea, and glossitis. In contrast, there are no known toxic effects if supplementation exceeds upper tolerable limits. The RDA is 30 mg/day for adult men and women, and no UL has been established.[9]

Folate

Folic Acid (Vitamin B9, Folate) is primarily known for its role in DNA synthesis and red blood cell formation in the bone marrow and is used to prevent neural tube defects in pregnancy.[7, 8] Folate is naturally found in food including fortified cereals, lentils and beans, organ meats, citrus fruits, and green leafy vegetables; whereas folic acid is the supplemental form and can be found in fortified foods.

The typical manifestation of folate deficiency is anemia followed by diarrhea, fatigue, irritability, and dyspnea. Populations at risk of deficiency include pregnant women, individuals with malabsorption syndromes, alcoholics, teens, and elderly individuals. Neural tube defects such as spina bifida or anencephaly may result when women are folate deficient during the early months of pregnancy.

There are no reports of toxicity or adverse effects associated with excess intake of folate, although recurrent use can mask vitamin B_{12} deficiency symptoms.[7, 8] The DRI is described as AIs for infants. RDA is 400 mcg/day for adults, pregnant women need 600 mcg/day and lactating women need 500 mcg/day. The UL is 1000 mcg/day.[9]

Cyanocobalamin

Cyanocobalamin (Vitamin B_{12}, Cobalamin) plays an important role as a coenzyme in protein synthesis and the formation of red blood cells. It is attached to intrinsic factors in the stomach and is only absorbed when it reaches the ileum, the main site for fat-soluble vitamin absorption. Vitamin B12 is mainly found in products of animal origin such as organ meats, eggs, fish, and dairy.

Similar to folate, Vitamin B_{12} deficiency also manifests with anemia, followed by constipation, poor balance, loss of appetite, and numbness and tingling in extremities. Individuals with poor diets, strict vegetarians, senior citizens, and those with severe chronic malnutrition are at high risk for this deficiency.[7, 8] Vitamin B_{12} toxicity has not been reported. The RDA is 2.4 mcg for adults. Pregnant women need 2.6 ug and lactating women need 2.8 ug. No UL was established.[9]

Minerals

Macrominerals

Calcium

Calcium is one of the most abundant minerals in the body and plays an important role in bone and tooth formation. Additionally, calcium is an intracellular cation that regulates blood clotting, cardiac function, nerve transmission, and muscle contractility. Calcium is found in any dairy and fortified dairy products, legumes, and dark leafy green vegetables. Signs of deficiency (hypocalcemia) manifest in children as stunted growth and weak bones. In adults, calcium deficiency can lead to osteoporosis (bone loss), tetany, paresthesia, hyperirritability, muscle cramps, and convulsions.[7, 8] Signs of toxicity (hypercalcemia) usually occur in milk-alkali syndrome, kidney stones, or renal insufficiency. Calcium absorption tends to decrease with increased age for both men and women, so bone health maintenance must be accomplished with vitamin D along with calcium supplementation.[7, 8] The RDA for calcium is 1000 mg/day for most adults (19–50 year-old men and women; 51–70 year-old men), 1300 mg for teenagers, and 1200 mg for those over 50 years. The UL is 2,500 mg/day (19–50 years) and 2,000 mg/day (>50 years).[9]

Phosphorus

Phosphorus is the second most abundant mineral after calcium and plays a vital role in energy, fat, amino acid, and carbohydrate metabolism, regulation of calcium, and phospholipid transport.[7, 8] Phosphorus intake can be achieved with virtually any food and is abundant in protein-rich foods such as meat, poultry, fish, and eggs, whole grains, milk and dairy products, chocolate, and soft drinks.

Phosphorus deficiency (hypophosphatemia) is rare but may occur in malnourished individuals and those with renal insufficiency taking medications. Toxicity (hyperphosphatemia) is not common but can promote paralysis, muscular weakness, arrhythmias, heart disturbances, and even death if it occurs.[7, 8] The RDA for adult men and women is 700 mg/day, and UL for adults varies from 3–4 g/day.[9]

Potassium

Potassium is known as the main intracellular ion responsible for nerve transmission, muscle contraction, carbohydrate, and protein synthesis, and water and acid-base balance. Food sources high in potassium include potatoes, oranges, tomatoes, avocados, bananas, soy products, spinach, cantaloupe, and dairy products.

Signs of deficiency (hypokalemia) include muscle weakness, cardiac arrhythmia, paralysis, bone fragility, decreased growth, weight loss, and even death, which is often seen in malnourished individuals.[7, 8] Excess potassium (hyperkalemia) can lead to paralysis, muscular weakness, arrhythmias, heart disturbances, and even death. For potassium, there are no specific RDA, AI, or UL.[9]

Sodium

Sodium is the main extracellular ion along with chloride and its main function is to regulate blood pressure, and glucose transport into cells, to stimulate nerves, and muscle contractions, and to maintain acid-base balance.[7, 8]

Sodium is found in many processed foods in the American diet such as salty snack foods, condiments, and dressings, cured and processed meats, canned products, grains, and pasta. Natural sources include meat, fish, poultry, eggs, dairy products, dark leafy vegetables, and grains. Sodium deficiency (hyponatremia) can occur from water overload, resulting in nausea, weight loss, confusion, coma, and even death.[7, 8]

Excess sodium (hypernatremia) is often seen in individuals with dehydration, malnutrition, and severe weight loss, and can lead to symptoms of confusion, high blood pressure, heart failure, and coma.[7, 8] There is no specific RDA set for sodium, the UL is 2,300 mg/day for adults.[9]

Magnesium

Magnesium is an essential mineral used by more than half of the cells in our body in processes such as normal muscle contraction, nerve transmission and function, heart rhythms, energy metabolism, and protein synthesis. Magnesium is present in most foods. Fruits and vegetables, dairy products, and grains contain the most abundant sources of magnesium.

Signs of deficiency (hypomagnesemia) can occur in malnourished individuals and lead to poor growth, confusion, loss of appetite, tetany, numbness, arrhythmias, seizures, and even death.

Excess magnesium (hypermagnesemia) can be seen with kidney failure, and cause nausea, osmotic diarrhea, appetite loss, muscle weakness, respiratory failure, extremely low blood pressure, and irregular heartbeat.[7, 8] The RDA is typically 420 mg for men and 320 mg for women. UL for supplemental magnesium for adolescents and adults is 350 mg/d.[9]

Macrominerals				
Mineral	**Roles**	**Sources**	**Deficiency Risks**	**Intake Suggestions**
Calcium	Plays an important role in bone and tooth formation, regulates blood clotting, cardiac function, nerve transmission, and muscle contractility	Found in any dairy and fortified dairy products, legumes, and dark leafy green vegetables	Stunted growth and weak bones, osteoporosis, tetany, paresthesia, hyperirritability, muscle cramps, and convulsions	1000 mg/day for most adults
Phosphorus	Helps with energy, fat, amino acid, and carbohydrate metabolism, regulation of calcium, and phospholipid transport	Meat, poultry, fish, and eggs, whole grains, milk and dairy products, chocolate, and soft drinks	Rare, but may occur in malnourished individuals and those with renal insufficiency taking medications	700 mg/day for all adults
Potassium	Main intracellular ion responsible for nerve transmission, muscle contraction, carbohydrate, and protein synthesis, and water and acid-base balance	Potatoes, oranges, tomatoes, avocados, bananas, soy products, spinach, cantaloupe, and dairy products	Muscle weakness, cardiac arrhythmia, paralysis, bone fragility, decreased growth, weight loss, and death in the extremely malnourished	No RDA
Sodium	Regulates blood pressure, and glucose transport into cells, stimulates nerves, and muscle contractions, and maintains acid-base balance	Salty snack foods, condiments, dressings, cured and processed meats, canned products, grains, pasta, naturally in meat, fish, poultry, eggs, dairy products, dark leafy vegetables, and grains	Nausea, weight loss, confusion, coma, and death	No RDA, but upper limit 2,300 mg/day for adults.
Magnesium	Used in normal muscle contraction, nerve transmission and function, heart rhythms, energy metabolism, and protein synthesis	Fruits and vegetables, dairy products, and grains contain the most abundant sources of magnesium	Poor growth, confusion, loss of appetite, tetany, numbness, arrhythmias, seizures, and death	420 mg/day for men 320 mg/day for women

Trace Minerals

Iron

Iron is the most abundant trace mineral, existing in all animal and plant cells. Functional iron is composed of two proteins: hemoglobin in red blood cells and myoglobin in muscle cells.[7, 8] The main function of iron is to carry oxygen from the lungs to all tissues and cells in the body and improve cognitive, immunity, and nerve functioning.[7, 8] The food sources rich in iron include meat, poultry, fish, eggs, legumes and beans, enriched grains, fortified cereals, and dried fruit.

The most notable sign of iron deficiency is anemia, accompanied by fatigue, weakness, pallor, pale conjunctiva, koilonychia (thin, spoon-shaped nails), impaired learning ability, pica, and tachycardia.[7, 8] Iron toxicity can occur from taking iron supplements daily or recurrent transfusions, and commonly manifests with vomiting, diarrhea, GI distress, and drowsiness.[7, 8]

The RDA is 8 mg for men and postmenopausal women; 18 mg for premenopausal women. Pregnant women need 27 mg/d and breastfeeding women need 9 mg.[9] Teenage girls (ages 14–18 years) need 15 mg of iron per day (27 mg if pregnant; 10 mg if breastfeeding). Teenage boys (ages 14–18 years) need 11 mg of iron per day. The UL for iron is 45 mg/d.[9]

Iodine

Iodine (Iodide) is part of the hormone thyroxine and aids in the production of T3 and T4 to maintain proper thyroid functioning, energy metabolism, in normal growth and reproduction, and the regulation of metabolism and temperature. Iodine can be found in iodized salt, seaweed, and shellfish. Iodine deficiency and excess can both cause an enlarged thyroid gland. Deficiency is often associated with weight gain, cold intolerance, thinning hair, cognitive impairment, decreased metabolic rate, and neuromuscular impairments.[7, 8] The RDA is 150 mg/d for both men and women. UL is 1.1 mg/day.[9]

Copper

Copper is an antioxidant that is vital in skeletal development, formation of red blood cells, immunity, and energy metabolism.[7, 8] Copper is mainly found in grains, enriched cereals, shellfish, legumes and beans, eggs, potatoes, and dried fruit. Copper deficiency is rare in adults, except in individuals with celiac disease. Symptoms of deficiency include anemia, decreased skin and hair pigmentation, and reduced immune response.[7, 8] Copper toxicity is also rare, but can occur in individuals with liver disease, leading to copper deposits in the brain, diarrhea, tremors, and liver damage.[7, 8] The RDA is 900 mg daily for men and women and UL is established at 10 mg/d.[9]

Zinc

Zinc is present in very small quantities in the body and its main function is to protect cell structures against damage from oxidation, make cells' genetic material, stabilize DNA and RNA, enhance insulin action, and increase taste acuity.[7, 8] Zinc is found in most protein foods like organ meats, meat, poultry, fish, and eggs. Deficiency is not common in developing countries, but when it occurs it can lead to reduced immune function, alopecia, poor wound healing, and decreased taste acuity (hypogeusia).[7, 8] Signs of zinc excess include vomiting, diarrhea, headaches, and exhaustion. The RDA is 11 mg for men and 8 mg for women. UL is 40 mg.[9]

Fluoride

Fluoride is the most abundant mineral in water and soil that aids in the formation of bone and teeth enamel. Sources of fluoride include fluoridated water, tea, mackerel, salmon, and some infant foods. Signs of deficiency include dental cavities, anemia, and potential bone thinning, and toxicity may lead to tooth mottling and discoloration, and neurological problems.7, 8 The RDA is 3–4 mg/d for men and women. UL is set at 10 mg/d.9

Trace Minerals				
Mineral	Roles	Sources	Deficiency Risks	Intake Suggestions
Iron	Carries oxygen from the lungs to all tissues and cells in the body and improves cognitive, immunity, and nerve functioning	Meat, poultry, fish, eggs, legumes and beans, enriched grains, fortified cereals, and dried fruit	Anemia, accompanied by fatigue, weakness, pallor, pale conjunctiva, koilonychia, impaired learning ability, pica, and tachycardia	8 mg/day for men and postmenopausal women 18 mg/day for premenopausal women
Iodine	Aids in production of T3 and T4 to maintain proper thyroid functioning, energy metabolism, normal growth and reproduction, and regulation of metabolism and temperature	Iodized salt, seaweed, and shellfish	Weight gain, cold intolerance, thinning hair, cognitive impairment, decreased metabolic rate, and neuromuscular impairments	150 mg/day for all adults
Copper	Vital in skeletal development, formation of red blood cells, immunity, and energy metabolism	Grains, enriched cereals, shellfish, legumes and beans, eggs, potatoes, and dried fruit	Anemia, decreased skin and hair pigmentation, and reduced immune response	900 mg/day for all adults
Zinc	Protects cell structures against damage from oxidation, makes cells' genetic material, stabilizes DNA and RNA, enhances insulin action, and increases taste acuity	Organ meats, meat, poultry, fish, and eggs	Reduced immune function, alopecia, poor wound healing, and decreased taste acuity	11 mg/day for men 8 mg/day for women
Fluoride	Aids in the formation of bone and teeth enamel	Fluoridated water, tea, mackerel, salmon, some infant foods	Dental cavities, anemia, potential bone thinning	3–4 mg/day for all adults

Summary

Micronutrients play many vital roles in basic biological functions as well as responses and adaptations to exercise.

With a working knowledge of micronutrients, fitness professionals are better prepared to identify potential symptoms of deficiency or overdose and refer the client to an appropriate healthcare provider.

Making specific diagnoses or recommendations is outside the Trainer Academy CPT Scope of Practice.

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Chapter 27

Supplementation

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Introduction

Dietary supplements are widely used by athletes and fitness enthusiasts alike.

The Trainer Academy Scope of Practice prohibits recommending specific dietary supplements. However, fitness professionals should have basic knowledge of the widely used supplements and performance-enhancing drugs since many clients take one or more of these substances.

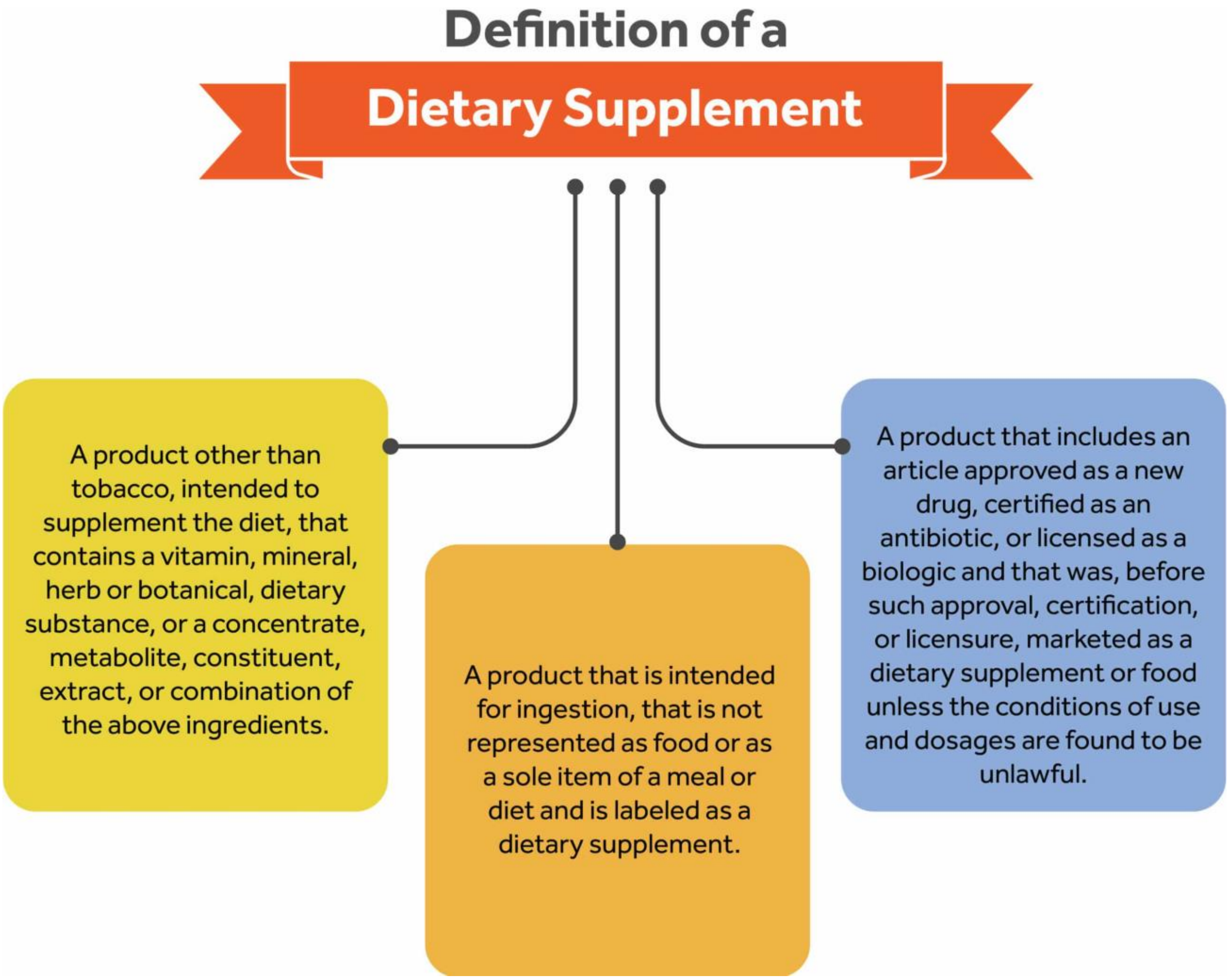
Furthermore, knowledge of the general purpose and proven efficacy of popular supplements, as well as understanding the regulations in the supplement industry is key for discussing safety and rationale for supplements when clients inquire.

Dietary Supplementation

A dietary supplement is a product that is intended to supplement the diet, and that contains one or more of the following: vitamins, minerals, herbs or other botanicals, amino acids, or other dietary substances for use by a human to supplement their diet by increasing their total dietary intake or concentrates, metabolites, constituents, extracts, or combinations of these ingredients.[14] A more comprehensive definition can be found below[15]:

A product other than tobacco, intended to supplement the diet that contains a vitamin, mineral, herb or botanical, dietary substance, or a concentrate, metabolite, constituent, extract, or combination of the above ingredients.

- A product that is intended for ingestion, that is not represented as food or as a sole item of a meal or diet and is labeled as a dietary supplement.
- A product that includes an article approved as a new drug, certified as an antibiotic, or licensed as a biologic and that was, before such approval, certification, or licensure, marketed as a dietary supplement or food unless the conditions of use and dosages are found to be unlawful.
- A product that excludes such articles which were not so marketed before approval unless found to be lawful. Deems a dietary supplement to be a food. Excludes a dietary supplement from the definition of the term “food additive.”



Dietary Supplement Regulation

The regulation of Dietary Supplements (DS) is overseen by two government agencies: the Food and Drug Administration (FDA), and the Federal Trade Commission (FTC).

The FDA is the major agency in the United States food supply that ensures food safety, monitoring, and inspection of animal products, sanitation, proper food labeling, food additives, genetically modified foods, and pesticides.[16]

The Federal Trade Commission (FTC) regulates advertising, including infomercials, for dietary supplements.[17] Both the FDA and FTC have the authority to take enforcement actions against dietary supplements and firms if they identify violations.

The FDA regulates dietary supplements under a different set of regulations than those covering conventional foods and drug products. In 1994, the Dietary Supplement Health and Education Act (DSHEA) was enacted to prohibit dietary supplement manufacturers and distributors from making false claims on supplement labels, to prohibit the manufacture and sale of adulterated dietary supplements, and categorized dietary supplements as food instead of drugs or dietary additives.[15]

However, many dietary supplements contain ingredients that have strong biological effects and can potentially conflict with a drug or medical condition.[14] A more comprehensive list of the federal law set forth by the DSHEA is listed below:

- It is advised that a company that introduces a new DS must send a notification including safety information to the FDA 75 days before selling the supplement.[18] This is not a requirement given that DS are classified as food products and not drugs.[19] The FDA is not authorized to approve dietary supplements for safety and effectiveness before they are marketed. In many cases, firms can lawfully introduce dietary supplements to the market without even notifying FDA.[19]
- A DS label must contain the product name and a statement that it is a "dietary supplement" or equivalent term replacing "dietary" with the name or type of dietary ingredient in the product (e.g., "iron supplement" or "herbal supplement"), all ingredients must be declared, and the name, place of business of the manufacturer, packer, distributor, and contact information must be displayed.[18]

A supplement facts panel defines how ingredients must be listed on the label.[18]

The label must also include the disclaimer, "This statement has not been evaluated by the Food and Drug Administration.[18] This product is not intended to diagnose, treat, cure, or prevent any disease," because only a drug can legally make such a claim. [18]

Manufacturers and retailers are not allowed to display product information or technical data sheets next to products. [18]

A DS label is no longer allowed to list disease states or make specific health claims on DS labels but can make "structure/function" claims and those are not subject to premarket review and authorization by FDA.[1]

Dietary Supplement Labeling Claims

Among the claims that can be used on dietary supplement labels, there are three categories of claims defined by FDA regulations: health claims, structure/function claims, and nutrient content claims.

Health claims

Health claims describe the relationship between a substance (whether a food, food component or dietary ingredient) and a disease or health-related condition.[18] A health claim can mention a disease state as long as it has met the significant scientific agreement standard of the FDA and can exist on foods and dietary supplements.[20, 21]

An example of a health claim is "soluble fiber from foods such as oat bran, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease." All health claims, whether authorized or qualified, require pre-market review by the FDA.[20, 21]

Authorized health claims

Authorized health claims must be supported by a significant scientific agreement that the proclaimed benefit of a food or food component on a disease or health-related condition is true.[20, 21]

An example of an authorized health claim is "low-fat diets rich in fiber-containing grain products, fruits and vegetables may reduce the risk of some types of cancer, a disease associated with many factors."

Qualified health claims

Qualified health claims have significant scientific agreement supporting the claim however there is insufficient evidence to approve them as health claims.[20, 21] An example of a qualified health claim is "consumption of omega-3 fatty acids may reduce the risk of coronary heart disease."

Structure-function claim

Structure-function claims describe the role of a nutrient or dietary ingredient intended to affect the normal structure or function of the human body.[20, 21] In addition, they may characterize how a nutrient or dietary ingredient acts to maintain such structure or function, for example, "calcium builds strong bones," "fiber maintains bowel regularity," or "antioxidants maintain cell integrity."

Structure/function claims for conventional foods focus on effects derived from nutritive value, while structure/function claims for dietary supplements may focus on non-nutritive as well as nutritive effects.[20, 21]

FDA does not require conventional food manufacturers to notify FDA about their structure/function claims, and disclaimers are not required for claims on conventional foods.[20, 21]

Nutrient content claims

Nutrient content claims describe the level of a nutrient in food using terms such as free, high, and low, or they compare the level of a nutrient in a food to that of another food, using terms such as more, reduced, and light.[20, 21] Nutrient content claims have been authorized by FDA and are made following FDA's authorizing regulations.[20, 21] An example of a nutrient content claim is a package of muffins that carries the claim "Low in Fat."

Vitamin and Mineral Supplements

Supplements Versus Whole Foods

The skyrocketing sales and use of supplements in the United States continue to expand at a rapid pace. Some of the reasons associated with supplement use in the American population are speculated to be related to the growing interest in food and nutrition in the maintenance of health and widespread availability.[22, 23]

In fact, in the US, over 50% of adults declare supplement use, and in some studies, almost 40% had taken dietary supplements during the previous 30 days when they were questioned.[22, 23]

In general, the scientific community and medical providers have come to the consensus that diversifying intake of whole foods is better assimilated and more effective at treating deficiencies than supplements alone. The most notable observed benefits in whole foods compared to supplements are:

1. **Food bioavailability:** whole foods including dairy, fruits, and vegetables offer greater nutrient density and micronutrient bioavailability compared to supplements. In simple terms, the bioavailability of vitamins in food means how much of a micronutrient is absorbed or made available to the body when consumed in the diet.[24] In contrast, supplements and fortified foods typically contain much higher amounts of nutrients than whole foods, but it is not guaranteed that the body can absorb them and put them all to use.
2. **Essential fiber:** a big proportion of whole foods such as cereals, fruits, and vegetables contain dietary fiber. While dietary fiber is derived from one of the macronutrients, it is not considered an essential macronutrient.[25] Given the increasing prevalence of Americans with suboptimal intakes of fiber, the Scientific Report of the 2020 Dietary Guidelines Advisory Committee acknowledges that fiber is a "nutrient of a public health concern due to the adverse health outcomes relative to its underconsumption."[10] When comparing supplement use to whole food consumption, supplements only provide an isolated source of the nutrient, and generally lack the fiber component necessary to meet the recommended daily intakes of fiber and observable health benefits that whole foods offer.

3. **Antioxidants and phytochemicals:** these compounds are naturally occurring in whole foods such as fruits and vegetables, whole grains, and legumes and play an important role in the prevention and treatment of chronic diseases. The main role of antioxidants and phytochemicals is to scavenge free radicals in the body and act as anti-inflammatory agents, ultimately protecting against cancer, aging, cardiovascular diseases, diabetes mellitus, obesity, and neurodegenerative diseases.[26]

Target Population

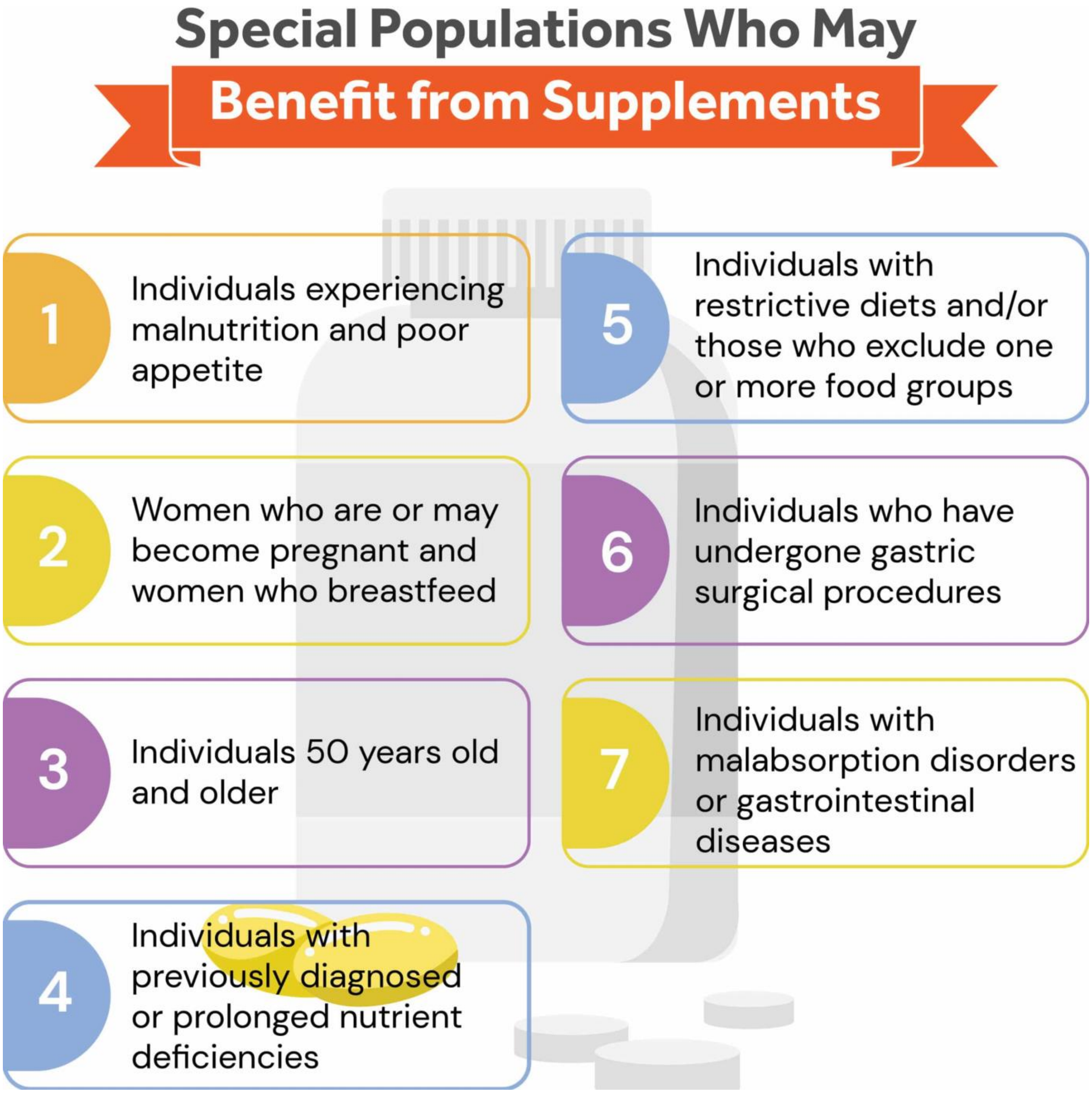
The literature has made it clear that the consumers of dietary supplements are mostly middle-aged and older adults. As it appears, the routine intake of supplements by healthy populations is not strictly tied to a particular disease state or micronutrient deficiency but rather taken for preventative reasons. And for this reason, people with healthier diets and lifestyles make it hard to study and determine whether vitamin and mineral supplementation offer the supposed benefits.

To this point, the literature continues to show that the taking of vitamin and mineral supplements by healthy people neither lowers their risk of cardiovascular diseases nor prevents the development of malignancies.[27]

With some exceptions, there is recognized evidence that omega-3 fatty acids lower blood triglycerides, but the extent that taking them prevents heart disease is ambiguous.[27] Similar examples follow this pattern for supplements intended to aid in weight loss and cancer prevention.

Populations Who May Benefit from Supplements

Certain special populations may benefit from specific supplementation. While it exceeds the Trainer Academy Personal Trainer Scope of Practice to recommend supplements to these populations, individuals in the following categories can benefit from certain supplementation protocols:



Toxicity and Safety

Toxicity

While it is difficult for food to cause nutrient imbalances or toxicities, supplements can easily lead to toxicity and adverse effects when routinely ingested in higher doses. The extent of supplement toxicity in the United States is unknown, but many adverse events are reported each year from overconsuming vitamins, minerals, essential oils, herbs, and other supplements.

Several committees, for example, the European Food Safety Authority (EFSA) and Institute of Medicine (IOM) have set tolerable upper intake levels (ULs) to prevent micronutrient toxicities. The DRI Tolerable Upper Intake Levels define the highest intakes of dietary vitamins and minerals that appear safe for most healthy people.[9]

This parameter is different from the Estimated Average Requirement (EAR), which assesses the average daily nutrient intake that is estimated to meet the requirements of 50% of the healthy individuals in a group.[9]

In other words, the EAR assesses nutrient adequacy in groups and ULs prevent the risk of adverse effects from excessive nutrient intakes.

Dietary supplement toxicity is the umbrella term that encompasses vitamin overdosage, vitamin overload, and hypervitaminosis. Vitamin overdosage and overload are observed with every vitamin and produce high blood and tissue levels of the vitamin itself. Vitamin overdosage is obtained only upon administration of high doses of a vitamin, while vitamin overload may originate from a variety of factors.[28]

Hypervitaminosis is a condition of abnormally high blood levels of a specific vitamin, generally, vitamin A and D, that either manifests as acute or chronic and is characterized by specific symptomatology.[28]

Megadoses of fat-soluble vitamins (A, D, E, K) can easily cause toxicity and should be taken with caution, particularly for individuals with medical conditions and pregnant women. Vitamin A toxicity is most notable and can cause nausea, vomiting, headache, dizziness, and blurred vision.[29]

While water-soluble vitamin toxicity is rare, folic acid overdose is common and can cause adverse events when taken in excessive doses, generally manifesting as reversible neurological complications.[30] Furthermore, some people may experience adverse effects from too much calcium or iron. In the case of iron toxicity, observable side effects include coma or low blood pressure, which can sometimes be fatal.

Iron overdoses can have long-term consequences on the intestines and liver, including intestinal scarring and liver failure.31, 32 Calcium toxicity is not as fatal as iron, but high calcium levels can cause serious heart rhythm disturbances, as well as kidney stones and damage to kidney function. Long-term overuse is often more serious than a single overdose.

Safety

Proving supplement safety is one of the many risks that the FDA bears under the DSHEA. In 2006, the Dietary Supplement and Nonprescription Drug Consumer Protection Act was signed into law, requiring mandatory reporting by manufacturers and retailers of known serious adverse events (AEs) related to dietary supplements and over-the-counter (OTC) medications.[33] Serious adverse events related to dietary supplements and drugs include life-threatening events, incapacitation, hospitalization, birth defects, and death.

The adverse effects associated with dietary supplements vary consistently in the literature. The most common supplements with health and safety concerns are those used for weight loss, performance enhancement (ergogenic aids), and sexual dysfunction.[34]

According to the FDA, these supplements have the highest risk of contamination and adulteration with unapproved dietary ingredients and pharmaceutical drugs.[35] A nine-year report published by the CDC found that among young adults aged 20-34, the most common supplements causing adverse events were weight loss and energy (ergogenic aids) and the most common symptoms were tachycardia, chest pain, and palpitations.[36]

For adults 65 and older, adverse events were mostly attributed to choking on micronutrient pills.[36] Up to date, only two dietary supplements have been banned by the FDA, Ephedra sinica in 2004, and dimethylamylamine (DMAA) in 2013, as being linked to cardiovascular toxicity and death.[35]

More recently, the FDA announced that N-acetyl-L-cysteine (NAC), used for chronic respiratory conditions, fertility, and brain health, is no longer included in the definition of a dietary supplement.[37]

Reporting Adverse Effects

The same year that the DSHEA was enacted, the National Institutes of Health founded the Office of Dietary Supplements (ODS).[41] The purpose of this entity is to increase awareness of dietary supplements, provide credible information to the public, and alert the public on current warnings and recalls as well as consumer tips for buying and taking dietary supplements safely.[41]

On the government website, consumers can find basic consumer information and a Dietary Supplement Label Database of dietary supplements used in the United States.[41] This database was developed to provide specific information on the ingredients in a supplement, technical data sheets about dietary supplements and herbs, and FDA warnings.[41]

In the event of a suspected serious health-related reaction or illness associated with a dietary supplement, alert a medical provider or healthcare professional knowledgeable in nutrition. In addition, reporting adverse reactions to supplements directly to the FDA via its hotline or website (FDA MedWatch) is highly recommended. Adverse event reports are forwarded to the Center for Food Safety and Applied Nutrition, where they are further evaluated by qualified reviewers.

Common General Health Supplements

Multivitamin/mineral Supplements

Multivitamin/mineral Supplements (MVM) have gained public attention over the years and are considered one of the most popular supplements on the market. The National Health and Nutrition Examination Survey (NHANES) found that between 2003 and 2006, the most commonly used supplements were multivitamins and multiminerals with at least half of the men and women 50 years of age or older regularly consuming them.[38]

In the years 2005–2012, the ten most popular of these, in order of decreasing prevalence of use, were vitamin D, vitamin C, calcium, cobalamin, vitamin E, folic acid, pyridoxine, niacin, vitamin A, and riboflavin.[38]

To date, there is no clear unanimity suggesting that MVMs help prevent chronic disease. In general, multivitamins from reputable sources without add-ons test free from contamination, and taking a daily dose of a basic MVM is unlikely to pose a health risk for most people.39

However, caution must be taken if consuming fortified foods and beverages along with dietary supplements. Reading the Supplement Facts label and percent daily value (% DV) to see what proportion of daily allotment one gets from taking a vitamin is generally considered safe to prevent toxicity.39

The biggest contraindication in MVMs use is that they have no standard scientific, regulatory, or marketplace definitions. Manufacturers determine the combinations and levels of vitamins, minerals, and other ingredients in them and therefore they have no standard regulations as to what nutrients they must contain or in what amounts.39

Furthermore, the definition of MVMs and evaluation of potential health effects varies greatly in the scientific literature. This concern and the fact that many dietary supplements are not labeled as MVMs even though they contain a variety of vitamins and minerals further complicates the study of MVMs.

Botanical and Herbal Supplements

Botanical and herbal supplements are dietary supplements that are increasingly popular among the public. In particular, athletes' use of herbal supplements is higher than that of the general public, and reasons for intake range from performance enhancement to immune function improvement to the prevention of illness or healing of injuries.[40]

However, regular ingestion of herbal supplements also raises toxicity and safety concerns among the scientific community. The reasons why controversies related to herbal dietary supplement intake exist include limitations in scientific evidence, premarket approval, and FDA regulation.

In general, most of the common herbs used in the United States do not pose a risk for a drug-nutrient interaction (DNI).[34] Out of the most commonly used herbal supplements, St. John's wort is the most problematic and has been shown to reduce the efficacy of many drugs, including antiretrovirals for HIV, antirejection medications for organ transplants, oral contraceptives, cardiac medications, chemotherapy, and cholesterol medications.[34]

Two other herbs have been shown to have a high risk for DNI, including goldenseal and black pepper in the supplemental form.[34]

Common Legal Performance Enhancing Supplements

Performance-enhancing substances (PES) are any substances taken in non-pharmacologic doses specifically used to improve athletic performance and alter one's appearance toward a more muscular and lean body. When surveyed, individuals reported using PES to improve physical appearance, increase muscle mass, optimize general health, and help meet physical demands on their bodies.[42]

Over the years, the literature has shown that PES in the athletic population has steadily increased and has been estimated internationally at 37% to 89%, with greater frequencies being reported among elite and older athletes.[43]

Among college athletes and nonathletes, prevalence rates of PES are also relatively high. In a study from 2008, at least 46% of male nonathletes and 56% of male athletes, as well as 25% of female nonathletes and 30% of female athletes, were using these substances.[44]

More recently, PES has become increasingly popular among adolescents and young adults and there is a growing trend of using PES as cognitive function enhancements for academic performance, attention, and memory, specifically through the use of neuroactive substances.[45]

In particular, a prospective cohort study from the National Longitudinal Study of Adolescent to Adult Health, Waves I to IV (1994–2008) identified 16.1 % of young men and 1.2% of young women from a sample of 12,133 young adults aged 18 to 26 years who used legal PES in the past year.[46]

Along with the increased usage of these products, there is an ever-growing cause for concern about not only their effectiveness but also safety. Since PES are mostly unregulated by the FDA and clinical trials lack data and regulation, inconsistencies exist on the legal status of PES in federal and state laws in the United States and medical outcomes associated with their use.

Legal PES can be classified according to the constituent ingredients, and the timing of the training. The most common legal PES that will be discussed in this chapter include: creatine, caffeine, protein and branched-chain amino acids (BCAAs), and beta-alanine.

Pre-Workout Supplements

Pre-workouts are supplements ingested before an exercise session or sporting event intended to increase mental focus, endurance, blood flow, strength, power, aerobic and anaerobic capacity, or overall perceived increase in energy level.

While a small amount of evidence exists for potential benefits when consuming a pre-workout supplement, inconsistencies within the literature remain when considering the specific dosages, populations, and types of activities performed.

According to the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine, the ingredients mentioned below are common pre-workout supplements that have been regarded as safe and have strong evidence to support efficacy.

Beta-Alanine

Beta-alanine (β-alanine) is a non-essential amino acid commonly found in meat, poultry, and fish. During exercise, the formation of lactic acid is likely to result if insufficient glucose is present in the body to be metabolized for energy.

This metabolic reaction lowers muscle pH levels and reduces the muscles' ability to contract, causing fatigue.[47, 48] The purpose of supplementing beta-alanine is to increase concentrations of carnosine, a proton that improves muscles and blood pH buffering capacity during high-intensity exercise, and reduces overall fatigue.

In addition, beta-alanine can increase time to exhaustion,[49] muscular endurance,[50, 51] anaerobic capacity,[48] and lean mass,[52] ultimately enhancing training capacity. The optimal dosage is set between 4 to 6 g/day for 2–4 weeks and is most effective when complimenting high-intensity exercises lasting 1–4 minutes, such as high-intensity interval training (HIIT) or short sprints.[47]

The only reported side effect is paraesthesia (i.e., tingling) but studies indicate this can be attenuated by using divided lower doses (1.6 g) or using a sustained-release formula.[47] At usual doses, beta-alanine appears to be safe for most healthy populations except for pregnant or breastfeeding individuals.

Caffeine

Caffeine is a central nervous system stimulant ubiquitously found in a variety of food and beverages such as coffee, tea, energy drinks, pre-workout supplements, over-the-counter diet pills, and medications. The ergogenic benefits of caffeine as a pre-workout have been documented.

Caffeine can reduce the perception of fatigue and allow exercise to be sustained for longer.[53] In addition, caffeine can increase muscular endurance, glycogen sparing during exercise, intestinal absorption of carbohydrates, fat utilization, and calcium release.[54]

The optimal dose of caffeine ranges from 3 to 6 mg/kg, approximately 60 min before exercise, and is most effective for high-performance athlete improvements.[54]

The FDA established that 400 mg/day of caffeine is a safe amount of daily consumption for the general population.[55] Higher doses of caffeine (9–13 mg/kg) do not result in an additional improvement in physical performance and are associated with a high incidence of side effects such as nausea, anxiety, and insomnia.[56]

The most commonly reported side effects of caffeine are tachycardia, heart palpitations, anxiety, headaches, and insomnia quality, and its use should be discontinued for individuals taking stimulant medications, anticoagulants, monoamine oxidase inhibitors, and quinolone antibiotics.[54, 57, 58, 59]

Creatine

Creatine, usually sold as creatine monohydrate is an amino acid produced by arginine and glycine, two non-essential amino acids. Approximately 2 grams of creatinine can be obtained daily from dietary sources such as meat and fish.[60]

Creatine supplementations elevate muscle creatinine levels and increase ATP regeneration by delaying the onset of muscle fatigue during high-intensity exercise and increasing the capacity of the skeletal muscle to perform work during periods of alternating exercise.[61] The classical loading protocol consists of ingestion of 0.3 grams/kg/day of CM for 5 – 7 days (e.g., ≃5 grams taken four times per day) and 3–5 grams/day thereafter.[62, 63]

The performance benefit of creatine supplementation has been primarily observed in short-duration, maximum-intensity resistance training, and strength training.[64]

Conflicting evidence appears in studies assessing the effect of creatine on endurance sports. In healthy individuals, creatine supplements are generally safe when taken both short and long term and no adverse effects from consuming recommended doses of creatine supplements have been documented.[65]

Since supplementation has the potential to raise creatinine levels and mimic kidney disease, creatine supplementation should not be used by individuals and athletes with pre-existing kidney disease or those with a potential risk for kidney dysfunction.[66]

Post-Workout Supplements

Protein

Protein as an ergogenic aid can be found in many foods, from animal and vegetable whole foods, powders, shakes, gels, and bars. Powdered protein can come from various sources, including eggs, milk (e.g., casein, whey), and plants (e.g., soybeans, peas, hemp). Some protein powders can contain protein from multiple sources (e.g., plant-derived).

The ergogenic effects of protein as a post-workout supplement have been well documented in the literature, claiming that its purpose is to provide sufficient "building blocks" for muscle and lean tissue growth after the body's resistance to acute high-intensity training.

As a result, damage to contractile proteins and muscle soreness occurs, which can last for several days and may impair muscle function. In these circumstances, an adequate intake of protein may increase synthesis, whereas its absence increases the rates of protein degradation resulting in a negative net protein balance.

In theory, protein supplementation stimulates protein synthesis that aids in the growth and repair of contractile proteins, thereby facilitating long-term recovery and muscle remodeling.[67, 68, 69, 70]

According to the American College of Sports Nutrition, the Academy of Nutrition and Dietetics, and Dietitians of Canada, there is a lack of evidence from well-controlled studies that protein supplementation directly improves athletic performance.[71]

However, protein supplementation in the presence of adequate carbohydrate intake during the recovery period may delay muscle damage and soreness.[71] The extent to which protein supplementation improves resistance in athletes is contingent on a variety of factors, including intensity and duration of the training, individual age, dietary energy intake, and quality of protein intake.[71, 72]

For athletic individuals engaging in strenuous exercise that seek to build and maintain muscle mass, the International Society of Sports Nutrition recommends an overall daily protein intake of 1.4–2.0 g/kg of body weight/day.[72] For resistance-trained individuals higher protein intakes (>3.0 g/kg/d) may have positive effects on body composition (i.e., promote loss of fat mass). These protein doses should ideally be evenly distributed, every 3–4 h, across the day.[72]

In addition, it is advised to take protein supplements with caution as they are considered dietary supplements with no FDA approval for safety or effectiveness. In particular, protein supplements often contain processed materials and lack other essential nutrients required for the sustenance of a healthy lifestyle.

It is suggested that the required protein intake be obtained from natural whole food sources and protein supplementation should be resorted to only if the protein is insufficiently available in the normal diet.

Protein supplements appear to be safe for the general population, and to date, there is limited information available concerning the possible side effects of long-term supplementation. To date, the only adverse effects reported come from protein powders and claim symptoms of gastrointestinal discomfort, increased risk of weight gain and uncontrolled blood glucose from added sugars and calories, and contamination with non-protein ingredients.

A more recent report found that many protein powders sold recently contained heavy metals (lead, arsenic, cadmium, and mercury), bisphenol-A (BPA, which is used to make plastic), pesticides, and other contaminants with links to cancer and other health condition.[73]

Reading the nutrition and ingredient labels and consulting with a physician, sports dietitian, or athletic staff beforehand is recommended to prevent contamination with banned substances that are not listed on the label.

Branched Chain Amino Acids (BCAAs)

Branched chain amino acids (BCAAs) include leucine, isoleucine, and valine, three essential amino acids that are chemically structured with a branch side-chain that form one-third of the total protein in the body[74] and are the only amino acids metabolized by the skeletal muscles.[75] BCAAs must be obtained from external sources such as protein foods like chicken, red meat, fish, and eggs because the body can't produce them.

The three BCAAs are unique among the EAAs for their roles in protein metabolism, neural function, and blood glucose and insulin regulation.[72] In the last decade, consumption of BCAAs in the form of dietary supplements has increased among recreational exercisers and athletes based on the potentially efficacious effects on reduction in protein degradation, muscle damage, feelings of soreness, and fatigue after ingestion post-exercise.[76, 77, 78]

A combination of 3.2 g BCAA and 2.0 g taurine, three times a day, for 2 weeks before and 3 days after exercise was a useful strategy for reducing delayed muscle soreness and muscle damage.[79]

While short-term intake of leucine has the potential to improve protein synthesis, long-term trials do not support BCAAS as useful performance enhancers that accelerate the repair of muscle damage after exercise.[72]

In addition, caution must be taken when ingesting high intakes of leucine, as it can potentially disrupt the normal action of insulin and dysregulate blood glucose, making increased

BCAA concentrations and their metabolites responsible for insulin resistance and complications associated with diabetes.[80, 81]

The excess of BCAA may lower brain uptake of other neutral amino acids, such as phenylalanine, tyrosine, HIS, and tryptophan (TRP), which are precursors of dopamine, norepinephrine, histamine, and serotonin.[82]

Ethical, Legal, and Health Issues with Illegal Performance-Enhancing Drugs

Epidemiology and Use

Performance-Enhancing Drugs (PED) are pharmacological substances that are commonly used by competitive, professional, Olympic athletes, and non-athlete weightlifters to improve performance, muscle recovery, and prevent nutritional deficiencies.

The most common PEDs include anabolic-androgenic steroids (AAS), beta 2 agonists, peptide hormones, diuretics, cannabinoids, blood doping, narcotics, beta-blockers, and corticosteroids, human growth hormone, erythropoietin, diuretics, and stimulants.

The use and prevalence of PEDs use have increased dramatically over the past decade. To date, it has been estimated that there are at least 3 million PED users in America, which puts PED use on a scale similar to commonly encountered diseases such as Type 1 Diabetes and HIV.[83, 84]

Although steroid use is widespread in many Western countries, the United States appears to be the leading country in AAS use.[83, 84] In addition, a systematic review that sampled between 1976 and 2019 from 35 countries estimated that the rates of doping prevalence in competitive sports ranged between 0 and 73%, with most falling under 5%.[85]

The vast majority of PED users are not athletes but rather nonathlete weightlifters, and the adverse health effects of PED use are greatly underappreciated. Furthermore, the individuals who are particularly vulnerable for use of performance-enhancing substances are adolescents. Among athletes who use PEDs, those who play football, baseball, and basketball, who wrestle, and who are involved in gymnastics and weight training are at increased risk.[84]

Purpose and Adverse Effects

Androgenic-Anabolic Steroids

Androgenic-anabolic steroids (AAS) are synthetic derivatives of the male hormone testosterone. Testosterone is a male sex hormone and the most common androgen that helps promote the development and maintenance of male sex characteristics.

Androgens also have anabolic effects such as an increase in skeletal muscle mass and strength. Athletes and nonathlete weightlifters take AASs orally, transdermally, or by intramuscular injection; however, the most popular mode is the intramuscular route.[34]

Oral preparations have a short half-life and are taken daily, whereas injectable androgens are typically used weekly or biweekly.[34]

The primary effects of AAS usage include[34] :

- Muscle fiber hypertrophy
- Increased tissue net oxygen delivery
- Increased bone mineral density
- Increased blood cell production
- Decreased body fat
- Increase heart, liver, and kidney size
- Vocal cord changes
- Increased libido
- Mood and motivation

The main effects of short- and long-term AAS use that athletes most often self-report are an increase in sexual drive, the occurrence of acne vulgaris, increased body hair, and an increment of aggressive behavior.[34]

Adverse effects of PEDs use have also been reported in the literature, particularly, associations with increased risk of death and a wide variety of cardiovascular, psychiatric, metabolic, endocrine, neurologic, infectious, hepatic, renal, and musculoskeletal disorders.[83]

These drugs have also been implicated in stroke, seizures, and such adverse psychiatric conditions as anxiety, mood changes, and autonomic hyperactivity.[86] "Steroid rage" has been cited as a cause of aberrant behavior in some adolescent males.[87]

It also is associated with other high-risk behaviors, such as the use of other illicit drugs, reduced involvement in school, poor academic performance, engaging in unprotected sex, aggressive and criminal behavior, suicidal ideation, and attempted suicide.[34]

Human Growth Hormone

Human growth hormone (HGH) is a naturally occurring metabolic hormone secreted by the pituitary gland. In healthy adults, HGH enhances carbohydrate and fat metabolism, helps to maintain sodium balance, and stimulates bone and connective tissue turnover.[34]

In addition, HGH regulates protein through anabolic effects including protein oxidation sparing, increasing lean body mass, and decreasing fat mass.[34] Despite these physiological effects, there is not enough evidence to suggest that HGH administration enhances physical performance or has adverse effects on HGH.

Therefore, most of the information is anecdotal, and these reports are often confounded by concurrent use of other PEDs, especially AASs. The potential side effects include edema, excessive sweating, skin changes, darkening of moles, adverse effects on glucose and lipid metabolism, and the growth of bones as evidenced by the development of a protruding jaw and boxy forehead.[34, 83]

Erythropoietin

Erythropoietin (EPO) is a glycoprotein hormone that regulates red cell production and is produced by both the kidney and the liver. In adults, the kidneys are the dominant source of circulating erythropoietin, although the liver is an important contributor to erythropoietin production in the fetal and perinatal periods.

EPO injections are used in the athletic population to increase the serum hematocrit and oxygen-carrying capacity of the blood and delivery to the muscle and thereby improving endurance.[34]

While EPO use as an ergogenic aid is popular in endurance sports, such as distance running, cycling, and triathlons, it is difficult to detect because it is a hormone produced by the kidneys.

The usage of EPO augments the risk of thrombosis, cardiovascular or cerebrovascular events (including myocardial infarction and stroke), and hypertension.[34] EPO also can cause elevated blood pressure or elevated potassium levels.[34]

Common Performance-Enhancing Drugs

Androgenic-anabolic steroids (AAS)

- Synthetic derivatives of testosterone
- Anabolic effects such as increased skeletal muscle and strength
- Side effects: increased risk of death and a wide variety of physical disorders

Human growth hormone (HGH)

- Metabolic hormone that can be taken exogenously
- Enhances carbohydrate and fat metabolism
- Stimulates bone and connective tissue turnover
- Insufficient evidence for performance-enhancing benefits
- Side effects: edema, excessive sweating, skin changes, adverse effects on glucose/lipid metabolism, and bone growth changes

Erythropoietin (EPO)

- Glycoprotein hormone that regulates red blood cell production
- Produced by kidney and liver but can be taken exogenously
- Injections used to increase serum hematocrit and oxygen-carrying capacity of blood and delivery to muscles, improving endurance
- Side effects: elevated blood pressure, elevated potassium levels

Legality Issues and Regulations

The use of PEDs is banned in major sports organizations that regulate sporting competitions to protect the health and well-being of athletes and ensure fair play in Olympic sports. In competitive sports, the term doping is used to define the use of banned athletic performance-enhancing drugs by athletic competitors.

To prevent that, the World Anti-Doping Agency (WADA) is an international agency that oversees the implementation of the anti-doping policies in all sports worldwide and maintains a list of substances (drugs, supplements, etc,) that are banned from use in all sports at all times, banned from use during competition, or banned in specific sports.[88]

The WADA's Anti-Doping Program is based on the WADA Code, a universal core document that contains anti-doping policies, and rules and regulations for best practices in international and national anti-doping programs.[89] It works in conjunction with eight mandatory international standards and 12 non-mandatory guidelines.[89]

The WADA's Prohibited List is a mandatory International Standard that gets updated at least annually, with the new list taking effect on January 1st each year.[90] Any substance that is added to the prohibited list is deemed to meet two of the following criteria[90]:

1. It has the potential to enhance or enhances sport performance
2. Use of the substance or method represents an actual or potential health risk to the athlete
3. Use of the substance or method violates the spirit of sport

Additionally, the list is divided into the substances and methods that are prohibited at all times, or prohibited only in competition.[90] Those substances banned at all times would include (but are not limited to) hormones, anabolics, EPO, beta-2 agonists, masking agents, and diuretics.[90]

Those substances prohibited only in competition would include but not be limited to stimulants, marijuana, narcotics, and glucocorticosteroids.[90] Also banned at all times are methods such as blood transfusion or manipulation, or intravenous injections in some situations.[90]

It is important to remember that not all substances and methods are named on the Prohibited List.[90] Even if not expressly named, a substance and method can be deemed prohibited if[90]:

- It is not currently approved by any governmental regulatory health authority for human therapeutic use (e.g. drugs under pre-clinical or clinical development or discontinued, designer drugs, substances approved only for veterinary use), or
- It has a similar chemical structure or similar biological effect(s).

Above all, athletes are responsible for knowing what substances and methods are considered banned on the Prohibited List.

Under World Athletics Rules, the presence of a prohibited substance in an athlete's sample, the use of a prohibited substance, and prohibited method all constitute a doping offense.

It is important that those who work with athletes acquaint themselves with WADA's List of Prohibited Substances and Methods.

The National Collegiate Athletic Association (NCAA) also bans the use of PEDs and recreational drugs to protect the health of college athletes and ensure fair play.[91] The NCAA tests for steroids, peptide hormones, and masking agents year-round and tests for stimulants and recreational drugs during championships.[91]

Member schools also may test for these substances as part of their athletics department drug-deterrence programs.[91] A positive drug test will result in loss of eligibility and suspension from the sport, including the risk of negatively impacting health.[91]

Summary

The popularity of dietary supplements and even performance-enhancing drugs mean that fitness professionals routinely discuss them with clients in the context of health and fitness.

While making supplement recommendations is outside the Trainer Academy Scope of Practice, certified trainers can discuss research on the efficacy and safety of supplements, as long as they do not prescribe them to the client.

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Chapter 28

Exercise, Mental Health, and Lifestyle Considerations

Patricia Lininger, MS

Introduction

There is a reciprocal relationship between mental health, a positive healthy lifestyle, and exercise. In addition to exercise and fitness training, fitness professionals can deliver coaching toward healthy lifestyle practices, which can be highly beneficial for clients.

The effects of such habits as proper exercise, nutrition, and other wellness practices can result in mental and emotional health improvements.

As with all other aspects of personal training, fitness professionals must be aware of the limits of their scope of practice when it comes to mental health and lifestyle coaching.

The role of a personal trainer can be broad as the trainer guides a client to a myriad of improvements in all health and wellness pillars. The benefits of the personal trainer's guidance include enhanced quality of life for the client through improved physical condition and fitness levels.

This in turn affects overall physical health but can include facilitating greater confidence, a more positive outlook, and improved mental and emotional health based on reaching new fitness peaks

These holistic improvements can be achieved through the trainer's coaching the client to adopt healthy lifestyle habits, including the following:

- Getting enough quality sleep
- Hydrating adequately
- Practicing good nutrition habits
- Managing stress
- Limiting alcohol
- Quitting smoking

For coaching clients to improve their lifestyle habits, personal and in-depth discussions and analysis of the client's current lifestyle practices must take place.

These discussions are more readily accomplished when a high level of trust is established between the client and the personal trainer, which precipitates greater compliance with the coaching.

However, with such a level of trust, the definitive line marking the scope of practice boundaries of a personal trainer can become hazy and a client's expectations can exceed the scope of practice limitations.

It is not uncommon for a client to perceive their personal trainer as their professional mental health counselor, encroaching into the scope of practice for a licensed mental health professional.

Providing services outside the scope of practice can result in a personal trainer losing their accreditation or even may result in expensive legal action against the trainer.[1, 2, 3]

The boundaries of the professional scope of practice for a personal trainer must be maintained, yet it is the personal trainer's responsibility to decipher what might be an overstep into a licensed health professional's scope of practice.

To be careful not to overstep the boundaries of other licensed professional domains, the personal trainer should not:

- Counsel or advise
- Diagnose
- Attempt to heal disease or treat/rehabilitate an injury
- Prescribe medication, supplements, dietary plans, or other approaches to prevent, treat, or cure any disease

The personal trainer can avoid the legal liabilities by remembering that they serve as a guide or facilitator, helping the client reach their own conclusions and helping them problem solve versus problem-solving for them.

Lifestyle coaching should be a client-led collaborative process that guides the client to analyze, think, plan, set goals and work towards them.

To guide a client, a personal trainer would be wise to practice coaching techniques which include active listening, reflective listening, and motivational interviewing, which is not unlike the practice of a counselor. However, a personal trainer should not directly advise a client on how to handle problems or manage the personal aspects of their lives.

The trainer should exhibit empathy and compassion, impart no judgment when listening to a client express their concerns or daily experiences, and acknowledge the client's feelings expressed. However, a personal trainer will be outside their professional scope of practice if he or she provides counsel.

The personal trainer can be an educator of evidence-based strategies and techniques for improved fitness, health and wellness, mental well-being, confidence, self-improvement, and empowerment.

Sharing quality resources from evidence-based sites and publications is one way to begin exposing clients to new information that may inform their decision making. Allowing the client to be the decision maker in the collaborative process will be best for the client's chances for success.

Counseling Referrals

If a personal trainer perceives that a client needs professional counseling, a referral should be made to a licensed counselor, psychologist, psychiatrist, or social worker in a non-insulting and nonjudgmental manner.

The statements above refer to common venting on personal issues from a client who perceives the trainer as a confidant. However, If the situation seems extreme and/or if there is any indication that the client is in danger of harming themselves or others, a direct question regarding their intentions for harm should be asked. If the answer affirms such intentions, emergency personnel should be contacted. A suicide hotline should be contacted if self-harm is intended.

Similarly, when coaching or training a client with the adoption of healthy nutrition habits, the personal trainer must not infringe on the scope of practice of a registered dietitian. The personal trainer should not recommend specific diet plans or quantities of nutrients nor should they offer advice on supplementation. However, they can help the client track food intake and educate them on evidence-based healthy nutrition plans and portion control, provide quality science-backed resources, and help the client analyze and determine healthier choices.[2]

Likewise, as a personal trainer instructs a client on exercise and designs an effective exercise plan, they must not infringe on the scope of practice of a physical therapist, medical doctor, or another licensed practitioner.

The personal trainer cannot decide whether it is safe for the client to exercise and must refer the client to an appropriate licensed professional if they suspect the client may have an issue that makes exercise unsafe.

In summary, it is the personal trainer's responsibility to respect the boundaries between them and licensed professionals in all overlapping fields.

There is a risk for liability if a personal trainer's action could be in any way construed to have contributed to any harm to a client, but any actions that can be interpreted as operating beyond the scope of practice of a personal trainer can be cause for legal action.

The Benefits of Physical Activity on Mental Health

Good mental health is often determined by self-reports of positive moods, resilience, a lack of any significant or consistent anxiety or depressive symptoms and the ability to regulate emotions.

In an era with high incidence of mental health issues, many health professionals and affected individuals are searching for all avenues to assist in improving mental health.[4]

Many studies link exercise and consistent physical activity with better mental health and even more studies are being conducted on this topic every year.

In one such study with a large test group of 1.2 million American adults, it was recorded that those who exercised regularly exhibited better mental health than those who did not, taking in account other factors such as background and demographics.[5]

In one of the many meta-analyses, researchers found a correlation between exercise and positive mental effects for those with mental health disorders, as well as those without. These effects were most evident in those who had exhibited higher levels of anxiety and depression.[6]

In this review, the findings concluded that regular rhythmic moderate or low intensity aerobic exercises delivered the most improvements. In some case improvements in anxiety and depression were evident after just one bout of exercise of 15-30 minutes in duration.[6]

According to another meta-analysis on the prevention of anxiety and depression, more than over 80,000 participants across multiple studies showed that participating consistently in physical activity reduced the chance of suffering higher anxiety levels or developing an anxiety disorder.[7]

On the other hand, lower activity levels correlated with greater risks of less-than-optimal mental health.

Another study review including more than 250,000 people across 49 studies showed that consistently participating in more physical activity reduced the chance of suffering from depression.[8]

As for improvements in the mental health of those who suffer from more severe mental health disorders, research concludes that marked symptoms such as adverse moods, difficulties with focus and concentration, dysfunctional sleep habits and other symptoms of psychosis improve with physical activity and exercise.[9]

Personal trainers assist their clients not only with improving their physical health, but also their mental health and well-being, which then, affects every aspect of their lives.

How to Maximize the Mental Health Benefits of Exercise

- Encourage clients to exercise outdoors. Time spent in nature was also proven to provide mental health benefits, so combining the two may provide a double boost.[12]
- Have clients choose activities they like for exercise/physical activity.
- Let clients choose several short bouts of exercise in a day versus one long one if the single workout seems daunting. It was proven that several 10-minute bouts were as effective as a 30 minutes single session.[13]
- Encourage clients to take rest days and listen to their bodies. Exercise can become a dreaded chore when it creates excessive stress.

- Encourage small celebrations after activities using positive language and expressions. The feelings that result from a mini-celebration give a boost of dopamine that fosters the desire to repeat the activity that brought about such feelings.[14]
- Listen to enjoyable music during exercise. Studies prove music decreases stress and boosts positive feelings.[15]
- Practice mindfulness (for example, notice the birds or the plants on a walk or jog outdoors, listen for the sounds around when taking a swim.) Attune all senses to the experience.[26]

Helping Clients Identify and Practice Healthy Behaviors

Clients can often make great leaps in their health and fitness goals once they adopt healthier lifestyle habits. Trainers can facilitate these changes in all lifestyle pillars. There are many studies supporting this potential for boosting mental health, moods, cognitive functioning, and more when improving these four lifestyle habits.

Hydration

Some clients may not recognize the correlation between hydration and mental health, so it is essential to educate them on the need for water intake and the many benefits it bestows to both physical and mental health.

One study revealed that drinking less than 2 glasses of water every day more than doubled the risk of depression for women and increased the risk by more than 70% in men.[16]

Additionally, links between obesity, metabolic disorder, and inadequate water consumption have been established which feeds into the mental health aspect, as those with obesity and other health issues have higher rates of depression as well.[17]

There is growing evidence that lack of adequate water consumption is linked with mental health disorders.[16] Research suggests even slight dehydration adversely affects mood and the perception of the difficulty of a task for women.[18] Likewise, a study on healthy young men showed a decrease in alertness and memory and increased feelings of fatigue and anxiety when moderately dehydrated.[19]

The first objective as a trainer and coach could be to help the client identify his or her current hydration habits by tracking them daily, then setting goals to increase the amount of water they drink in the day.

Awareness of inadequate hydration often prompts extra efforts and tracking can provide both accountability and awareness.

Examples for a trainer to follow could include having the client determine a small goal of increasing his or her water consumption and then having them problem-solve as to what they can employ to prompt the behavior throughout the day.

If they can't think of solutions, the trainer could provide a list of suggestions and let them choose. They might put a sticky note on their desk and check off tally marks, they may fill up a water glass when they get coffee in the morning and then do it again each time they get up to use the restroom.

They may buy an attractive new water jug and keep it in a prominent place. The trainer can start the list of suggestions to get them thinking and then ask them to finish it. The idea is for them to come up with what might inspire them to maintain adequate hydration.

Sleep

Adequate sleep is another healthy habit that should not be ignored for improving both physical and mental functioning and health. It is, therefore, imperative when working with a client to discuss their sleep patterns and educate them on the evidence-based value of 7-9 hours of quality sleep each night.

Helping a client to identify their current sleep patterns by tracking and analyzing them, and then strategizing on ways to improve these patterns where necessary can greatly improve their rate of success in reaching health, fitness, and wellness goals.

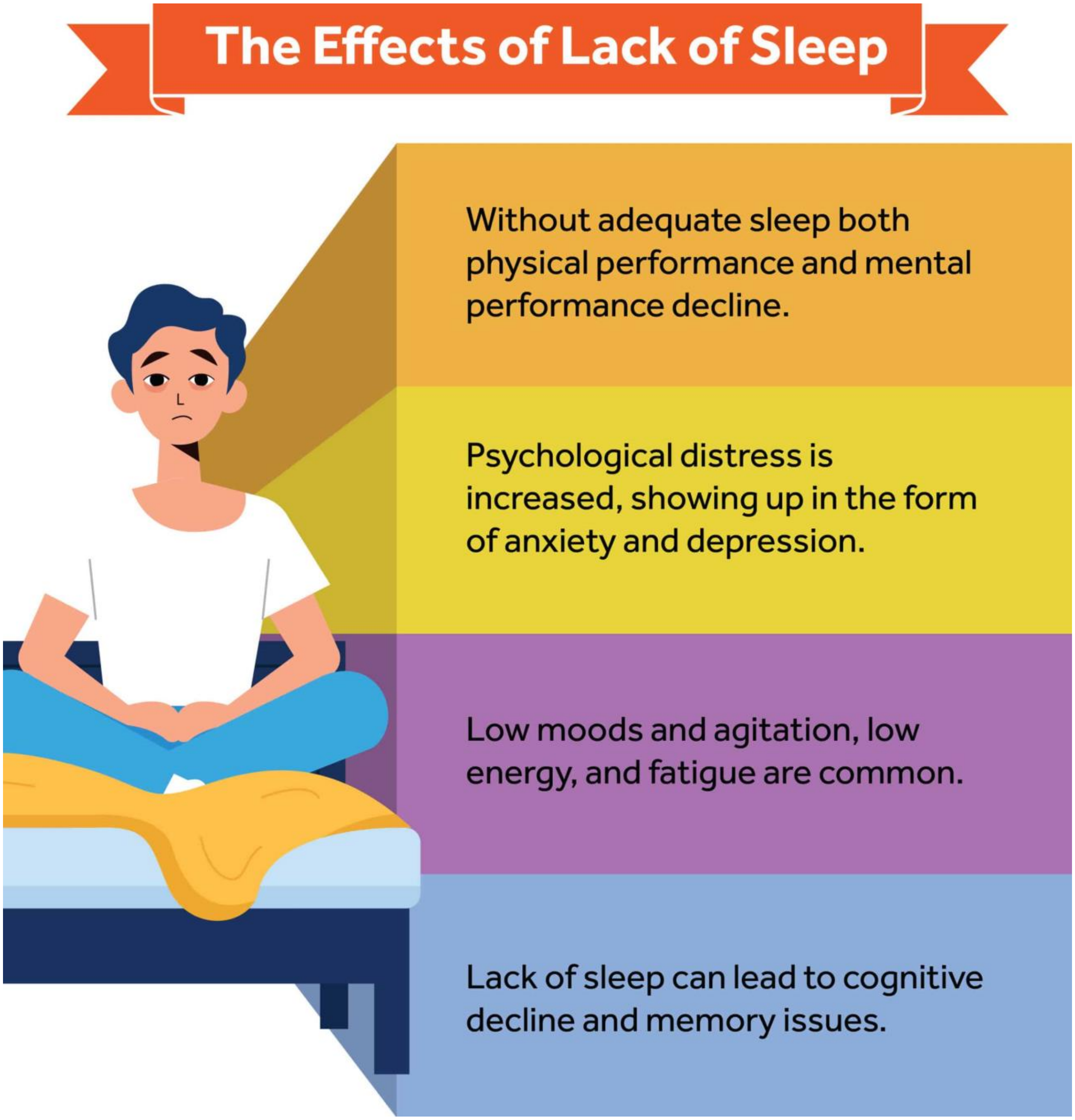
It is reported that one-third of US adults report getting less than 7-9 hours of sleep as recommended by the CDC.[20] Without adequate sleep, both physical performance and mental performance decline. Psychological distress is increased, showing up in the form of anxiety and depression, low moods and agitation, low energy, fatigue, and even cognitive decline and memory issues.[21]

Both short sleep duration and poor quality of sleep have associations with depression.[21] One study of over 28,000 people concluded that mental health was negatively affected by both inadequate quantity and poor quality of sleep.[21]

Earlier, researchers in the US found that inadequate sleep duration (less than 7-9 hours per night) and sleep problems within the duration were linked with higher levels of clinical depression.[22]

It has even been observed that individuals averaging 6 or fewer hours of sleep per night were approximately 2.5 times more likely to experience frequent mental distress than the participants who sleep consistently more than 6 hours.[20]

As with hydration, having clients track to become aware of their current patterns can often inspire more adherence to the recommendations. Tracking can be done simply with pen and paper logging bedtime and wake-up time and any waking throughout the night. Many apps are also available for smartphones and smartwatches and fitness trackers can track sleep time, as well as the quality of sleep.



Exercise can often be a remedy for sleep problems for those who have trouble getting to sleep or staying asleep, but if sleep problems persist, collaborate problem-solving with clients regarding other lifestyle changes such as stopping screen time in the evening, eliminating caffeine or alcohol, taking an evening walk, meditating, listening to calming music and other strategies can be tried.

As always, let the decision-making of strategies be client-led. The personal trainer simply facilitates problem solving with open-ended questions and active listening.

If sleep problems persist, a referral to a sleep specialist or counselor should be made.

Nutrition

Good nutrition habits can result in more energy and vigor, healthy digestion, greater focus and alertness, improved moods, greater exercise and sports performance, better mental health, cognitive functioning, and more. In short, good nutrition can affect all bodily functions and is instrumental to overall good health and wellness.

As a personal trainer, providing evidence-based resources on healthy nutrition plans is expected, however, as in the previous segment on mental health, it is the responsibility of the trainer to not overstep the boundaries of the personal trainer's scope of practice.

The role of a personal trainer is to both help their clients identify and practice the recommendations for consuming a balanced diet consisting of health-promoting nutrients and to share quality science-backed resources.

Alcohol limitation and Smoking Cessation

It would be rare to find a client who does not already know that smoking is an unhealthy habit or that drinking too often or too much is also not good for your physical or mental health either.

Although there are personal trainer scope of practice limitations when it comes to counseling, fitness professionals can be a source of guidance and support for clients wanting to stop smoking or those who want to refrain from drinking excessively.

Smoking Cessation

As for smoking cessation, according to a report by the CDC, about 70% of adult smokers have proclaimed they want to quit, yet only about 1 out of 10 successfully quit each year.[24]

Dependence on tobacco often takes strong intervention and several tries before success.

With those track records, a personal trainer should consider referring the client to a smoking cessation practitioner who is highly trained in this specific area and works diligently with the latest evidence-based practices. The personal trainer can continue supporting the client at the same time.

One of the many resources available to share with clients who want to quit is a government "quit line" provided by the CDC which uses evidence-based practices and can be called 24 hours per day.

English: 1-800-QUIT-NOW (1-800-784-8669)

Spanish, 1-855-385-3569.

Mandarin & Cantonese: 1-800-838-8917

Vietnamese: 1-800-778-8440

State Quit-Lines can be found at map.naquitline.org Visit www.cdc.gov/tobacco/campaign/tips/quit-smoking for additional resources to share.

Additionally, nicotine replacement medications such as the patch, nicotine gum and nicotine lozenges can be helpful. Although a personal trainer would not be in the scope of practice to prescribe or recommend a product, they can learn more about these to answer questions and send the client to the websites that educate on the details including recommended dosage and duration of use.

Motivational interviewing techniques common in health coaching and behavior change guidance techniques are again, a great way to allow the client to fully engage and make decisions. These techniques keep the trainer or coach within the scope of practice by supporting and facilitating, not advising.

Limiting Alcohol Consumption

Educating a client on the risks and the adverse effects on physical health and mental health of drinking too much or too often is certainly within the scope and helping a client track, analyze and define their current drinking habits are as well.

Assist the client in identifying their true perspectives about their habits along with setting goals first. The client must also take note of the triggers that prompt excessive drinking and brainstorm solutions for avoiding or countering them. Finding replacement behaviors is another task for the client. Again, the client is the one solving the complex problem and the personal trainer cannot give advice.

Since drinking heavily can be a sign of an addiction, recommending a counselor, a mental health professional or even a rehabilitative treatment program is usually the best choice. This needs to be done tactfully and without judgment.

When allowing the client to explore their present habits, goals, and the barriers to achieving them with open ended questioning, the client might come up with this need for treatment on their own.

Strategies for Trainers to Encourage Healthy Lifestyles

The following is a list of a few practical tips for fitness professionals to encourage healthy lifestyles in their clients:

- Model healthy behaviors to help inspire clients to adopt such habits.
- Share resources where healthy lifestyles are modeled and the rewards of those lifestyles are visible, which provides a subliminal message that encourages others to make healthy choices.
- Hold the client accountable while utilizing positive approaches.
- Acknowledge and celebrate the small wins to encourage continued efforts.

- Provide positive yet sincere affirmations encouraging clients to scaffold one small win onto another.
- Encourage clients to set goals small enough to be reached but big enough to be satisfying, and then build on their success once each small goal is reached.

Summary

The role of the fitness professional includes guiding clients towards improvements in all health and wellness pillars. Just as exercise creates better physical and mental well-being, further health and wellness improvements such as proper sleep, hydration, and better nutritional choices can drastically improve health and fitness outcomes.

Additional lifestyle habits include limiting the use of substances like cigarettes and alcohol, which is something fitness professionals can discuss with clients.

In all cases of behavioral and lifestyle coaching, it is imperative that fitness professionals stay within the Trainer Academy Certified Personal Trainer Scope of Practice.

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Chapter 29

Legal and Professional Guidelines for Personal Trainers

Michael Caceci, MS

Introduction

Fitness professionals and personal trainers must follow a number of legal and professional guidelines when training clients in any capacity. This includes knowing the scope of practice, obtaining proper certifications, following proper standards of care, obtaining necessary paperwork from clients, and ensuring a clean and safe facility.

Healthcare professionals include most individuals credentialed through licenses, certifications, and registrations in a field relevant to human health. Each of these professionals provides services which identify, prevent, and treat injuries and diseases.

When an individual needs treatment, they visit with their primary care physician. When that physician encounters a situation outside of their scope of practice, they refer their patient to another healthcare professional who can provide specific services (such as a registered dietician to provide nutritional information or an orthopedist to treat a bone-related issue).

While other professionals may provide general guidelines for physical activity, it is the certified personal trainer (CPT) that develops exercise programs for healthy individuals to help improve and maintain their fitness goals. Certified personal trainers are often the bridge between the medical community and those who exercise. Physicians are often called on to recommend physical activity to their patients, but only 30% of patients report hearing this advice from their doctor.[4]

All personal trainers should stay within the scope of practice equivalent to their training and experience, following the recommendations of other healthcare professionals. When a client is referred by a physician, it is necessary to get permission from the client to communicate with their doctor in order to keep the doctor abreast on how the client is doing and to see what recommendations the doctor may have.

Physician's orders take precedence over the fitness professional, since they will have a more complete understanding of the client's health and medical history. The trainer must remain cognizant of their own role in order to avoid any legal problems and provide the right types of services for which they are qualified. This will also help develop relationships with the other medical professionals who are linked to this client as well and create good cohesion, and the trust to refer more clients to the trainer.

The Trainer Academy CPT Scope of Practice

The Trainer Academy CPT scope of practice encompasses working with apparently healthy individuals or people with health conditions who have been cleared to exercise by an appropriate healthcare professional.

Scope of Practice for Trainer Academy Certified Personal Trainers:

- Training apparently healthy individuals to improve aerobic and muscular fitness
- Training individuals with medical conditions who are cleared by physician for exercise
- Training 1-on-1 or in small groups
- Coaching clients on developing realistic fitness goals
- Designing appropriate fitness training programs for specific goals
- Instructing safe exercise technique
- Supervising exercise equipment use
- Conducting preparticipation health screenings
- Conducting physiological measurements (heart rate, blood pressure, weight)
- Assessing cardiovascular fitness
- Assessing muscle strength and endurance
- Assessing flexibility
- Providing basic general nutrition information

The Trainer Academy CPT scope of practice prohibits:

- Diagnosing or treating any illness or injury
- Prescribing medications or supplements
- Making specific meal plans or dietary recommendations
- Monitoring medical conditions
- Rehabilitating or providing counseling for any conditions

Liability Guidelines for Personal Trainers

The trainer should understand areas of liability associated with the delivery of their service and how to minimize these risks by following standards and guidelines established by professional organizations.

Along with a comprehension of how to develop safe and effective exercise programs, personal trainers must obtain liability waivers from all clients prior to bringing them into the equipment area.

Proper Certification

Although there is no one governing body over exercise and no specific qualifications as far as education or certification, the primary purpose of each certification is to protect the public from harm. Becoming certified is the first step prospective trainers must take to minimize the risk for the client and liability for themselves.

With a certification from a National Commission for Certifying Agencies (NCCA) accredited organization, fitness professionals prove that they have met minimal competencies and that they possess the knowledge, skills, and abilities to develop safe and effective exercise programs.

Certification and adherence to industry recognized standards will serve to maintain professionalism, reduce liability, and give guidance to the client as far as the trainer's credentials.

Numerous professional organizations recommend hiring trainers who have an NCCA accredited certification. Certifications will require that trainers achieve continuing education units to maintain certification.

The Trainer Academy CPT is among the NCCA accredited certifications and has thus gone through the rigorous process to ensure the information and guidelines provided match the best practices in the industry.

The Trainer Academy CPT has a continuing education requirement of 20 credit hours every 2 years from a wide range of continuing education providers.

Standard of Care

Personal trainers must act as any reasonable and prudent professional would with the same level of training. If a lawsuit is brought against them, another professional may testify as to what they would have done in the same situation. Also, the position statements of prominent exercise organizations may be consulted to see if they conformed to these standards.

Confidentiality and Record Keeping

Since CPTs collect various health forms, personal information, records of training sessions, and payments made or due, the client's confidentiality will have to be protected. And in case of any litigation, trainers may need to reproduce documentation to prove that they performed appropriately.

Facilities and Equipment

Facilities that trainers may work in include commercial fitness centers, private studios, outside locations, or in a client's home. Regardless of location, trainers have a responsibility to make sure that they took all reasonable precautions to eliminate any hazards. If training in a gym, CPTs should make sure the floor is clean and equipment is put in its proper location. They should check local laws when training outdoors and inform clients of any potential risks.

Ensuring that clients are wearing appropriate clothing and footwear for the workout is another area of concern that the CPT should be aware of. All precautions that are undertaken should be documented and kept up to date in case they need to be produced.

Trainers use various apparatuses during workouts. It is important to use equipment from reputable manufacturers. CPTs should inspect equipment to make sure it is not damaged, it is clean, and it is safe to use.

Procedures should be in place to document that the equipment receives inspections, maintenance, and repairs. CPTs must make sure they are knowledgeable about the intended use of the equipment so that they will use it effectively and appropriately. Using equipment for unintended use will open the trainer up to liability.

Personal trainers should make sure that the client has been familiarized with the apparatus and has the physical aptitude to safely use a piece of equipment. They should make sure to have the appropriate pieces of equipment for the number of people they will be training so nobody is fighting over it and know how to substitute one piece of equipment for another in case something is not available when they go to train a client.

Emergency Response

In the event of an emergency, certified personal trainers should follow the facility procedures. Since Trainer Academy Certified Personal Trainers are required to maintain a valid CPR/AED certification, trainers should always respond as trained individuals in those certifications when responding to potential cardiovascular risks.

Facilities and Equipment

Safety Checkpoints

1. If training in a gym, CPTs should make sure the floor is clean and equipment is put in the proper location.
2. Check local laws when training outdoors and inform clients of any potential risks.
3. Ensure clients are wearing appropriate clothing and footwear for the workout.
4. All precautions that are undertaken should be documented and kept up to date in case they need to be produced.
5. Use equipment from reputable manufacturers. CPTs should inspect equipment to make sure it is undamaged, clean, and safe to use.
6. Procedures should be in place to document that the equipment receives inspections, maintenance, and repairs.
7. CPTs must make sure they are knowledgeable about the intended use of the equipment.
8. Personal trainers should make sure that the client has been familiarized with the apparatus and has the physical aptitude to safely use a piece of equipment.
9. Have the appropriate pieces of equipment for the number of people and know how to substitute one piece of equipment for another in case something is not available when CPTs go to train a client.

Risk Management

Proper risk management involves having policies and procedures in place as well as following industry standards and guidelines to show that CPTs took all possible precautions to ensure safety, minimize risk, and are prepared to handle any foreseeable emergencies.

Risk management plans should be multi-tiered. Written documentation showing that the facility and equipment is being surveilled for damage, maintenance, and repair should be kept on file, informed consent and waivers for all participants should be signed and up to date, and liability insurance should be procured by the CPT. The CPT should uphold all copyright laws as well.[1, 3]

Liability insurance will help to protect trainers from claims due to such things as accidents or negligence. When acquiring insurance, the CPT should make sure to check that the insurance provides proper coverage for the services they will be delivering and the settings that they will be working in and the amount appropriate to the level of risk.

Though CPTs will take every precaution to minimize any liability, accidents happen. Carrying liability insurance along with the practice of other risk management strategies are the best ways for personal trainers to protect themselves and their assets from possible litigation.

Summary

In conclusion, the CPT has many professional responsibilities. They need to understand their place alongside other healthcare professionals and how their services interact with them.

The CPT must adhere to their scope of practice and refer to the appropriate professionals when client’s present with conditions that fall outside the Trainer Academy Scope of Practice.

The CPT must also respond appropriately to emergencies, keep detailed records of all client waivers and incidents, and take steps to protect themselves against potential liability.

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Chapter 30

Client Safety, Injuries, and Emergency Situations

Michael Caceci, MS

Introduction

Keeping clients safe from injury and fitness professionals free from legal issues is paramount when training a client in any scenario. Fitness professionals must respond appropriately to emergency situations, understand the various injuries relevant to personal training, and maintain a safe training environment.

CPR/AED Importance

All fitness professionals must maintain an up-to-date adult CPR/AED certification, and ideally, first aid and infant CPR as well. Often, training facilities require all staff to have these certifications, and may provide certification classes. These certifications cover the steps to take in the event of a cardiac emergency or other first aid emergency situations.

Dealing with a cardiac emergency, such as a cardiac arrest where the heart stops, or a deadly arrhythmia such as ventricular fibrillation (VF), requires immediate action. Response time can mean the difference between life or death. The time between calling 911 to activate the EMS and the arrival of medical personnel may be longer than the victim will survive.

All training facilities should have an Automated External Defibrillator (AED) available, which drastically improves the effectiveness of CPR.

Emergency Safety

Before responding to any emergency, particularly when bodily fluids are involved, responders should wear personal protective equipment (PPE), which includes medical gloves, mask or face shield, eye protection, and if performing CPR, a CPR facemask. PPE is vital to protect the responding individual from various communicable diseases including hepatitis and HIV.

CPTs must wear gloves whenever there is a need to touch anyone to deliver emergency care. They should have a face shield with a one-way valve to protect themselves when giving rescue breaths during Cardiopulmonary Resuscitation (CPR). Following the standards of Universal Precautions and treating all bodily fluids as a biological hazard is imperative. This will protect CPTs from blood borne pathogens like Human Immunodeficiency Virus (HIV) and Hepatitis.

When responding to an emergency, fitness professionals should always call 911 or activate the facility's emergency procedures, then provide appropriate care within the scope of their training. The fitness professional should not attempt to give care beyond the scope of any certifications they have. Since fitness professionals must be CPR certified, responding to cardiac emergencies and related conditions is within the Trainer Academy Certified Personal Trainer Scope of Practice.

Acute Injuries

Personal trainers may encounter clients with injuries to various tissues of the body like muscle, tendons, ligaments, cartilage, and bones. These injuries may be pre-existing, but can also occur during the exercise session, particularly if the client misses a key form checkpoint or fails a heavy lift.

Pre-existing injuries and risk factors are screened via the health history and PAR-Q forms and discussed between the trainer and client prior to beginning any exercise.

Clients with a history of soft tissue injury should undergo rehabilitation under the supervision of a physical therapist prior to working with a fitness professional. However, many clients will have low grade, nagging injuries that may or may not be rehabilitated. In this case, any movement that causes pain should be avoided, and corrective exercises should be used to address any obvious muscular imbalances.

Diagnosing or treating any injury is outside the Trainer Academy Certified Personal Trainer Scope of Practice, but being able to identify and respond appropriately to common injuries such as strains, sprains, and fractures is an important skill.

The appropriate response to injuries should be to contact emergency medical personnel, begin the PRICE treatment, and refer the client to the appropriate healthcare professional once the acute situation has been addressed.

The PRICE Treatment

The PRICE treatment is an acute process for addressing tissue injuries and consists of the following:[1]

- Protection
- Rest
- Ice
- Compression
- Elevation

Protection involves preventing further injury by removing the stress to the injured area. Rest or restricted activity, especially weight bearing involves inactivity to the injured area, but not necessarily complete bed rest.

Ice should be applied 10-20 minutes every hour for 24-72 hours. Ice will reduce pain and inflammation. Trainers should not apply ice directly to the skin surface; have a cloth or some type of barrier between the ice and skin. Compression is achieved by putting a compression wrap that covers above and below the injured area. Elevation is accomplished by raising the injured body part 6-12" above the heart. This helps to reduce inflammation.

Regardless of the type of musculoskeletal injury the tissues will go through 3 stages of healing. The stages are[2]:

- Inflammation
- Repair
- Remodeling

During inflammation, which may last for up to six days depending on the severity of the injury, the goal is to immobilize the area to prevent further injury and to prepare the tissue for healing during the subsequent phases. Rest, ice, compression, and elevation are recommended at this stage.

The repair phase begins approximately three days after the injury and may last for up to twenty-one days. During this stage damaged tissues are healed and replaced, and scar tissue is formed. New connective tissue is laid down.

Collagen, which is the component of the new connective tissues and strongest when parallel to the line of stress, is laid down in a transverse alignment, which does not allow for optimal strength of the new tissue.

The goals during this stage are to prevent muscle atrophy, joint degeneration, promote collagen resynthesis, and prevent damage to newly formed collagen fibers. During this stage low load stresses may be used cautiously to prevent loss of joint motion and to promote collagen synthesis.

The phase of remodeling begins around day twenty-one and may last up to two years. The goal during this phase is to strengthen the newly formed tissue by helping the collagen fibers to align in parallel. Increased loading may be used to help the newly formed collagen fibers to strengthen and line up parallel to the line of stress. During this phase clients may continue exercises performed during the repair phase and activity specific exercise may be added.

The rehabilitation process above is generally beyond the scope of personal training and should be overseen by a licensed physical therapist.

Common Injuries and Issues

Tendonitis/Bursitis/Fasciitis

Tendonitis, bursitis, and fasciitis are inflammatory conditions that typically result from repeated microtrauma caused by overuse.

Tendonitis is an inflammation of tendons, which connect muscle to bone.[4,6] Bursitis is an inflammation of bursa which are fluid filled sacs that act like ball bearings in joints.[3,4] Fasciitis is the inflammation of a band of connective tissue.[4,5]

These injuries often occur from repeated microtrauma or overuse. The repetitive stress causes inflammation of the respective tissues. Insufficient warm up, overtraining, and previous injury can be underlying causes.

General symptoms of these three conditions include localized pain, pain with activity, and weakness. Proper response and treatment consist of conservative management which includes rest, avoidance of contraindicated activities, ice, heat, physical therapy, anti-inflammatory medication, and cortisone injections. Ice should be used initially before heat.

If any of these inflammatory conditions is suspected, the fitness professional should refer the client to the appropriate professional.

When the injury is stabilized, heat may be used before activity and ice may be used after activity. If there is severe pain, loss of function, or the injury doesn't respond to conservative treatments in 2-4 weeks, a doctor referral is recommended. Program modifications to restore strength, muscle balance, and flexibility along with a proper warm and myofascial release techniques of the area are recommended.

Muscle Strain

Muscle strains (or pulled muscles) occur when there is an overstretching or tearing of the muscle.

Strains may be the result of an acute macro traumatic event or microtrauma resulting from repetitive overtraining. In either case, the result is pain, inflammation, and possible loss of function.[7]

The symptoms and grievousness are dependent on the grade of the strain.

- Grade 1 strains are mild with tears occurring to only a few fibers with the muscle being painful and tender.
- Grade 2 strains are a moderate tear with a greater number of fibers being affected. This results in pain, point tenderness, inflammation, bruising, mild swelling, and noticeable loss of function.
- Grade 3 strains are complete tears of the muscle that result in loss of function, extreme pain, point tenderness and inflammation along with bruising.

Initial response for strains involves the PRICE acronym. A physician's referral may be warranted depending on the grade of the strain.

Risk factors for strain in the fitness context include improper warm up, muscle fatigue, muscle imbalance, poor flexibility, bad posture, and fluid and electrolyte depletion. Painful activities will have to be avoided and exercise programs will need to be modified to promote strengthening, muscle balance, and flexibility to the strained muscle.

Since muscles, tendons, and ligaments respond to the stress or lack thereof put on them, long periods of immobilization are detrimental to healing and can lead to atrophy. Full recovery time for muscle strain depends on the grievousness of the strain, the muscle injured, and length of immobilization. Common areas for muscle strains are the shoulder, hamstring, knee, hip, and calf.

Suspected strains should be assessed by a qualified medical professional prior to resuming training with the injured area.

Ligament Sprains

Ligaments connect bone to bone and provide stability for joints. A sprain is an overstretching or tearing of a ligament. This may result in a complete displacement (known as a luxation) or a partial displacement (a subluxation). The amount of tearing that occurs will determine the grade of the sprain.[8]

- Grade 1 sprains are minimal tears that result in minor swelling, pain, and loss of function.
- Grade 2 sprains result in the complete tearing of some but not all fibers resulting in moderate pain, swelling, and loss of function.
- Grade 3 sprains are complete tears and rupture of the ligament resulting in severe pain, swelling, and loss of function.

Sprains are serious injuries that require qualified medical care and warrant stopping activity until examined by a surgeon.

Return to activity will be dependent on the grade and location of the sprain. Exercise programs should be modified to continue progressing what was done in physical therapy. Sprains commonly occur in the shoulder, knee, and ankle.

Cartilage Damage

Cartilage provides shock absorption, lubrication, improves congruence, and increases the stability of joints. The primary cartilage structures of concern to fitness professionals are the medial and lateral menisci of the knee which may become worn from degeneration or damaged by a traumatic event. Symptoms include medial and lateral instability of the knee, pain, stiffness, and complaints of hearing a clicking sound with weight bearing activity.[9]

Chondromalacia a wearing away of the cartilage behind the patella is another source of complaints. It is the result of improper tracking of the patella on the femoral groove. Pain occurs behind the patella and walking up and down stairs exacerbates the symptoms.

Cartilage injuries should be assessed by a qualified medical professional prior to resuming training with the injured area.

Bone Fracture

A partial or complete disruption of bone tissue is known as a fracture. A fracture is classified as simple (closed) or compound (open). A simple fracture is one where there is no break in the skin while a compound fracture will result in breakage of the skin. Different types of fractures include longitudinal, oblique, transverse, and compression.

Concussions

Concussions are a serious head injury resulting from blows to the head. Loss of consciousness may occur, and the first signs are confusion and disorientation. Other symptoms include amnesia, headache, drowsiness, impaired speech, tinnitus, double vision, and sensitivity to light or noise. After a concussion the person is in a vulnerable state and a second injury could be disabling. A client suspected of having a concussion should receive immediate medical attention and cease physical activity immediately.[11]

Myocardial Infarction

Fitness professionals must be very familiar with the signs of myocardial infarction (heart attack) and stroke.

Angina pectoris is pain in the chest described as a crushing and squeezing feeling that is sometimes mistaken for indigestion. The pain can radiate to the neck, jaw, shoulder, or stomach as well as down the arms, especially the left arm since the heart is on that side of the chest. Clients experiencing angina pectoris may be having a heart attack and should be carefully monitored and receive qualified medical attention. This is particularly true if the client has risk factors for cardiovascular disease.[12]

Other symptoms of heart attack include vomiting, nausea, and cold sweats. Dyspnea or labored breathing that results in shortness of breath is possible as well. The symptoms may occur without chest pain. Screening clients ahead of time to ensure at-risk clients are carefully monitored is vital for ensuring client safety.[12]

Acute Stroke

Stroke is a leading cause of disability. Most strokes are ischemic and result from blockage of a blood vessel that supplies the brain. The other type of stroke is hemorrhagic and results from the rupturing of a blood vessel that supplies the brain. This may result from aneurysms, which are weak spots in the artery that form a balloon like bubble.[13]

Warning signs to look for include if the person is off-balanced when they walk, if they have slurred speech, droopy face, weakness, or numbness on one side of the body, partial or total vision loss, and severe headache.[13]

Symptoms will also be dependent on which side of the brain is affected. If the right side is affected the right side of the face and left side of the body will be affected. Weakness, numbness, vision, and memory loss may occur. When the left side of the brain is affected, the left side of the face and right side of the body will be affected. Weakness, paralysis, and speech and language impairments may be visible signs of stroke.[13]

An individual suffering a stroke requires immediate medical attention from qualified professionals.

Common Injuries & Acute Issues

Tendonitis
Tendonitis is an inflammation of tendons, which connect muscle to bone.

Bursitis
Bursitis is an inflammation of bursa which are fluid filled sacs that act like ball bearings in joints.

Fasciitis
Fasciitis is the inflammation of a band of connective tissue.

Muscle Strain
Muscle strains (or pulled muscles) occur when there is an overstretching or tearing of the muscle, the result of an acute macro trauma event or microtrauma resulting from repetitive overtraining.

Ligament Sprain
Overstretching or tearing of a ligament, resulting in a complete displacement (known as a luxation) or a partial displacement (a subluxation). The amount of tearing that occurs will determine the grade of the sprain.

Cartilage Damage
Wearing down of the cartilage that results in decreased shock absorption, joint lubrication, reduced congruence, and reduced stability of joints.

Bone Fracture
Partial or complete disruption of bone tissue, classified as simple (closed, no wound) or compound (open break in skin).

Concussion
Serious head injury resulting from blunt impact to the head.

Myocardial Infarction
Results from lack of blood or other disruption to the heart, can damage or destroy the heart muscle and disrupt heart rhythm and can be fatal. Commonly referred to as a heart attack.

Acute Stroke
The blockage of a blood vessel that supplies the brain. Hemorrhagic stroke can also occur, which comes from from the rupturing of a blood vessel that supplies the brain and may result from aneurysms.

Gym Maintenance and Hygiene

Client care and customer service are an integral part of personal training services. Fitness professionals must take all measures to ensure cleanliness and safety. Facilities and equipment should be clean, maintained and properly functioning. While fitness professionals may not be tasked with equipment maintenance, any observed malfunction, issue, or defect in equipment should be promptly reported and the equipment should not be used.

Trainers should make sure to wipe down equipment including mats after use. Hand sanitizer or wipes should be available to prevent the spread of any infections.

As a precaution it would be wise for coaches to wipe equipment before use too. Gym hygiene is everyone's responsibility, but personal hygiene is up to the individual trainer. The first impression a client gets of their fitness trainer may be based on appearance and demeanor.

A good trainer needs a professional standard and appearance. One way to do that is by being professionally dressed and groomed. Wiping down and cleaning equipment prevents the spread of disease, shows that they care and respect the people and place they work at.

Summary

Fitness professionals must be prepared to respond appropriately to a variety of potential emergency situations that may occur in the personal training environment. Emergency medical personnel should always be called in the event of a life threatening emergency.

Since Trainer Academy Certified Trainers are required to be CPR certified, they may respond to cardiac emergencies per their training.

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