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# CORRECTIVE EXERCISE

A Comprehensive Guide to Corrective Movement Training

First Edition Rev. 5/2021

INTERNATIONAL
SPORTS SCIENCES
ASSOCIATION

# ABOUT THE AUTHOR

Chad Waterbury is a graduate of the nation's #1 ranked Doctor of Physical Therapy (DPT) program at the University of Southern California (USC). Chad is a physical therapist, neurophysiologist, and author whose unique training methods are used by a wide range of athletes, bodybuilders, figure models, and fitness enthusiasts of all ages and from all walks of life.

Chad was the director of strength and conditioning at the Rickson Gracie International Jiu Jitsu Center in West Los Angeles and now works with professional athletes, celebrities and non-athletes one-on-one. Chad is the author of Huge in a Hurry and Muscle Revolution and contributes to many publications such as Men's Health, Men's Fitness, Fight! and T Nation.

Chad has a master's degree in physiology from the University of Arizona, where his focus on the neurophysiology of human movement and performance led him to make radical changes in the way he trains competitive athletes as well as nonathletic clients. His workouts are now shorter and faster, producing superior results in strength, power, and muscular development, while at the same time inducing less fatigue and allowing for shorter recovery periods between workouts.

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**Corrective Exercise:** A Comprehensive Guide to Corrective Movement Training
(First Edition Rev. 5/2021)

*Official course text for:* International Sports Sciences Association's Corrective Exercise Specialist Program

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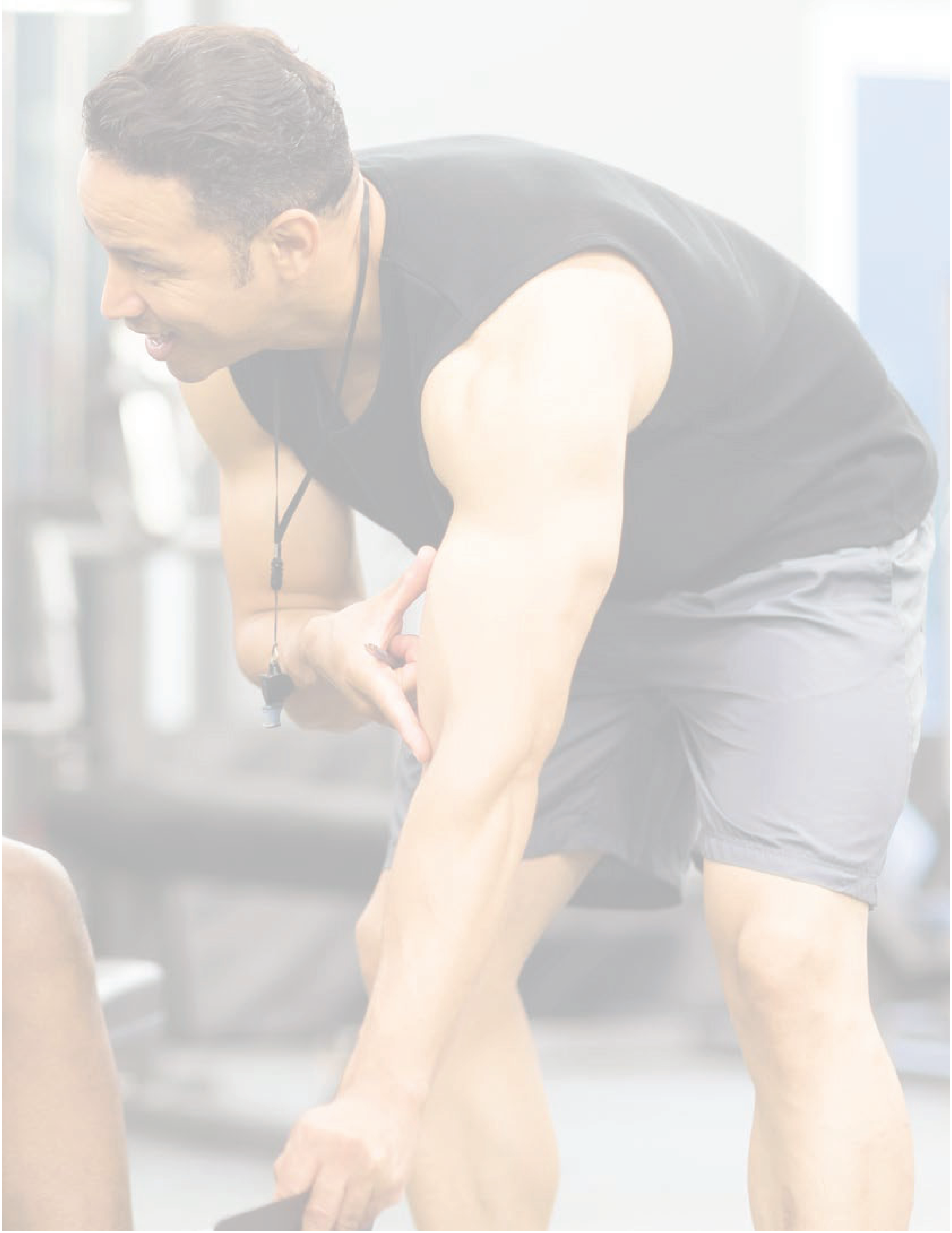


## TOPICS COVERED IN THIS UNIT



INTRODUCTION

# WHAT IS CORRECTIVE EXERCISE?

### What You'll Learn

In this unit, you'll learn how important both posture and exercise are for optimal health. You will also learn what has caused the surge in movement and postural dysfunctions over the last decade. Then we'll cover the three ways that corrective exercise can improve your client's life or sport. Finally, we will wrap up by outlining the perils of doing too little or too much exercise. By the end of this section, you should have a clear understanding of the necessity and benefits of corrective exercise.

# PLATO WAS RIGHT

I started working as a personal trainer in 1997, 18 years before I entered the doctor of physical therapy (DPT) program at the University of Southern California. At the time, there was a relatively clear separation between the roles of a **personal trainer** and those of a **physical therapist.**

**Personal trainer:** A person who instructs and prescribes exercise.

**Physical therapist:** A licensed health-care professional who helps patients reduce pain, improve mobility, and enhance movement patterns.

**Rotator cuff:** A group of tendons and four muscles that attach the upper arm to the shoulder blade.

A personal trainer helped people lose fat, gain strength, and build muscle (not always in that order), whereas the primary job of a physical therapist was to help patients overcome some type of physical dysfunction. It might be an acute injury, like a torn **rotator cuff**, or a chronic problem, like low back pain. But whatever it was, it was not something that anyone expected a personal trainer to understand, much less treat.

However, the line between the two professions has since blurred, thanks to a dichotomous shift in activity levels that I believe began in the mid-2000s.

**Figure I.1. Typical posture with a smartphone.** This posture results in excessive stress to the neck, spine, and shoulder joints.

We start with the fact that many people are now more sedentary throughout the day, which is one of the biggest **risk factors** for poor health. Inactivity is exacerbated by the fact that most people are doing things that encourage poor **posture**. Indeed, these days it is common for people to spend hours throughout the day with a rounded spine, anteriorly rotated shoulders, and a **forward head posture**, whether they're sitting at a desk or texting on a smartphone.

**Risk factor:** Any physical, psychological, or environmental factor that can increase a person's likelihood of developing an injury or disease.

**Posture:** The position of a person's body while standing, sitting, or moving.

**Forward head posture:** An anterior positioning of the cervical spine.

The average head weighs about 12 pounds. The soft tissues of the neck are typically well suited to stabilizing and balancing that load when it's positioned directly above the shoulders in what we consider "ideal" posture. However, for each inch the head moves forward, the supporting muscles must control an additional 10 pounds of weight. When your head is angled down 45 degrees—a common position while texting or working on a laptop—the load on the neck may be as much as 42 pounds. Not only does this strain the neck muscles, but it also can decrease your lung's **vital capacity** by 30%. Chronic forward head posture can increase curvature of the thoracic spine (i.e., **thoracic kyphosis**), which can increase **mortality rate** by 144% in older populations. Thoracic kyphosis can also increase the compressive loads on the **intervertebral discs** throughout the lower half of the spine.

Simultaneously, a significant increase in the number of people who engage in **high-intensity exercise** has occurred. This can include individual workouts focused on **powerlifting**; preparing for an extreme challenge such as a marathon, triathlon, or adventure race; or participating in group classes supervised by someone with minimal training and coaching experience. Many of the individuals in any of these circumstances are unprepared for these extreme challenges—because of a lack of fitness, poor **movement** quality, or inadequate instruction in specific exercises like the powerlifts and **Olympic lifts**.

People are generally more sedentary than ever, yet when they do move, they often perform workouts beyond their **strength**, **mobility**, and **motor-control** capacity. The convergence of these opposite ends of the fitness spectrum creates a large population of people with movement and postural dysfunctions that we rarely saw prior to the 21st century.

When one of them first experiences a problem, whether it's knee pain or a nagging discomfort in the shoulder, he or she will rarely make an appointment with a physical therapist or **physiatrist**. Instead, this person will go to a regularly scheduled workout and tell the trainer about the new problem. In my experience, it plays out something like this: "My shoulder hurts when I lift my arm overhead. What can we do to help it?"

In other circumstances, the trainer will observe a client's physical dysfunction before the client even realizes something is wrong.

That's why I believe it's essential for trainers to learn how to identify problems and to develop the knowledge and skills to provide solutions. I say this knowing that some physical therapists, **chiropractors**, and **medical doctors** disagree with this sentiment. After all, they have spent $100,000 or more to earn the degree and license that allows them to lawfully treat painful joints and bulging discs.

However, after two decades of training clients from all walks of life, I can say this with utmost certainty: Many physical problems do not require the intervention of a licensed clinician. The gym is often the best place to correct movement, eliminate pain, and restore performance, with no clinic or insurance copayment required.

Of course, some physical dysfunctions should only be treated by a qualified clinician, and I'll tell you how to identify the symptoms in Section Two of this course. Knowing what you *can't* do as a trainer—especially what you should never attempt—is just as important as is being able to recognize, assess, and correct the more common movement flaws and structural imbalances. My point is that a certified personal trainer can bridge the gap between simple, straightforward fitness training and more complex physical therapy offered by a health-care professional. Certified personal trainers can thus be the first line of defense against rising health-care costs.

As noted, movement and postural dysfunctions are more common than ever, and this trend has created a large and growing demand for Corrective Exercise Specialists. That is, an increased need for trainers and therapists who know how to recognize these problems and to correct them using the latest evidence-based interventions has arisen.

Plato was right: necessity is the mother of invention.

**Vital capacity:** The maximum amount of air that can be exhaled after a maximum inhalation.

**Thoracic kyphosis:** An abnormal forward curvature of the thoracic spine.

**Mortality rate:** The number of deaths within a specific population of people.

**Intervertebral disc:** The shock-absorbing, gel-filled structure between each vertebra.

**High-intensity exercise:** A form of exercise that requires a large percentage of a person's physical power.

**Powerlifting:** A strength sport that requires a person to lift the largest load possible for one repetition in the squat, deadlift, and bench press.

**Movement:** A physical motion occurring at one or more joints that is influenced by mobility, stability, posture, and motor control.

**Olympic lifts:** The snatch and the clean and jerk.

**Strength:** The maximal force that a muscle or muscle group can generate.

**Mobility:** The ability to move freely through a normal range of motion using minimal effort.

**Motor control:** The process of activating and coordinating muscles during movement.

**Physiatrist:** A physician who specializes in restoring normal function to the bones, muscle, and nervous system.

**Chiropractor:** A licensed clinician trained to restore interactions between the spine and nervous system.

**Medical doctor:** A physician who specializes in treating disease and injury with medicine.

**Movement dysfunction:** The faulty execution of an exercise or multiple-joint movement due to a lack of mobility, stability, posture, and/or motor control.

**Muscle imbalance:** When one muscle is stronger and/or stiffer than is the muscle that opposes its actions.

# BENEFITS OF CORRECTIVE EXERCISE

Given the widespread increase in **movement dysfunctions**, **muscle imbalances**, and joint aches that afflict both active and sedentary populations, corrective exercise is a necessary tool that seeks to help your clients achieve better results in their training and to move without restrictions throughout the day. You can deliver three primary benefits to clients once you become a Corrective Exercise Specialist.

## IMPROVE PERFORMANCE

The reason I entered a DPT program was to enhance my ability to identify and treat movement disorders. Before I enrolled in the program, many of my clients were professional athletes who wanted to take their strength, speed, or endurance to a higher level.

When I assessed these athletes, I frequently discovered muscle weakness, joint stiffness, or poor motor control—all dysfunctions that prevented my clients from achieving their performance goals. It was frustrating to realize I sometimes did not have the knowledge or skills to make the necessary corrections. The more I learned, and the more experience I accumulated, the better I became at helping my athletes. You'll be able to do the same with your own athletes and clients with the information in this course.

## RESTORE PERFORMANCE

Sometimes the goal is to help a client regain strength or to return to a previous level of occupational performance. Suppose for example that your client is a 40-year-old construction worker who hangs drywall for hours each day. The client is not concerned with how much weight they can add to their bench press. He just wants to be able to do his job without shoulder pain. Or imagine a dentist who spends hours a day bent over examining the teeth of his or her patients. The only goal is to get through the day without experiencing low backaches.

Sometimes your client will be an athlete whose goal is to perform without discomfort or movement restrictions. If that athlete is already at the top of his or her game, your job might be to help this person return to a previous level of performance, assuming the athlete's dysfunction does not require a medical intervention.

## REDUCE INJURY RISK

In explosive, chaotic sports such as basketball, football, soccer, and mixed martial arts (MMA), it's impossible for any athlete to always move with perfect body mechanics. And even if possible, he or she still wouldn't be able to control when or where contact with an opponent will be made. A wide receiver who takes a powerful medial hit to his knee just as he plants his foot is likely to suffer a torn **anterior cruciate ligament (ACL)** no matter how beautiful his stride may have been in the moment before the tackle.

**Anterior cruciate ligament (ACL):** A ligament that attaches on the femur and tibia that resists excessive motion at the knee joint.

The same applies to the ordinary world that we all must navigate. Sidewalks can be icy. Stairs can get slippery. Someone can accidentally bump into you at your most vulnerable moment. The list of unpredictable events is endless.

No trainer can make his or her client injury-proof. No amount of training or corrective exercise can offset the chaotic, unpredictable events of life and sports. But when the client's muscles and joints have sufficient strength and mobility, and when the nervous system can precisely control muscle activation, the client has a more **durable body**, which is the best defense against injury. That's what you can control and what you should strive to achieve in your training sessions.

**Durable body:** A body that is able to withstand wear or damage.

# TARGET AUDIENCE OF THIS COURSE

This course is designed to teach you, the fitness professional, how to identify and correct common muscular, neural, and soft-tissue problems related to movement. The course's goal is to improve the coaching and training guidance given by everyone from chiropractors to certified personal trainers.

How you use this information will depend on your professional status. Thus if you're a licensed clinician, and qualified to put your hands on a client, you can use corrective exercise as an adjunct to the manual therapies you provide to manipulate joints and treat soft tissue injuries.

However, many of you taking this course are not licensed and qualified clinicians. For you, this course teaches you to provide "hands-off" corrective exercise by visually assessing movements and positions. If the motion or posture is faulty or compromised, you'll learn to employ corrective actions, either through movement retraining or **soft tissue mobilization** without hands-on corrections. This strategy is the foundation of a Corrective Exercise Specialist's practice.

**Soft tissue mobilization:** The act of removing restrictions from muscles and connective tissues.

Research has mounted over the past 20 years that demonstrates the value of a hands-off approach using exercise and mobility training. This is especially true for the everyday back, knee, shoulder, and neck pain your clients experience and hope that you can address. This course is designed to help certified personal trainers and health-care professionals identify and correct those problems.

## HEALTH-CARE PROFESSIONALS

A health-care professional is someone who is trained and qualified to use a hands-on approach with patients recovering from acute injuries or experiencing chronic pain. This category includes chiropractors, physical therapists, and **athletic trainers**, all who have a license that allows them to put their hands on a patient.

**Athletic trainer:** A health-care professional trained to help prevent and treat physical injuries.

## CERTIFIED PERSONAL TRAINERS

A certified personal trainer is someone who is only qualified to teach exercises, whether it's resistance training, stretching, or something in between. Because certified personal trainers are not health-care professionals, they should minimize any hands-on therapy and limit their coaching to verbal cues and minimal tactile feedback.

Importantly, a certified personal trainer is not qualified to work with clients who have pain. All clients with pain should be referred to a health-care professional before you employ any of the guidelines and techniques outlined in this course.

# CORRECTIVE EXERCISE DEFINED

The goal of corrective exercise is to improve movement to enrich a person's life or sport. It seeks to identify the complex factors associated with poor movement patterns and correct them with the simplest methods possible. Sometimes you can help a client move better with nothing more than hands-off soft-tissue mobilizations on a few overly stiff muscles. The client will be "fixed" within one or two sessions, and you'll look like a genius.

Often, though, the solution will require a multifaceted approach that includes static and dynamic assessments, soft-tissue mobilizations, corrective exercises, and reassessments over the course of months. That's how long it takes to make permanent changes within tissues and **motor programs**. Nevertheless, when you master the information and techniques outlined in this course, you will have the skills to help your clients move better within the first session, no matter how long it takes to fix the underlying issues.

**Motor program:** A relatively automatic movement pattern produced by the nervous system.

One problem you'll encounter is your clients' belief that rest is the answer to just about any physical problem they experience, whether it's a sprained ankle or chronic back pain. Sometimes a few days off can indeed help, especially when walking itself is contraindicated, as it would be with the aforementioned ankle sprain. The problem, however, is that doing too little can be just as dangerous as doing too much.

Inactivity also has an opportunity cost. Current research demonstrates that challenging corrective exercises, when performed within a training program, create long-lasting changes to the structures and **synapses** of the brain and **nervous system**.

**Synapse:** The area of communication between two neurons or between a neuron and muscle.

**Nervous system:** The brain, spinal cord, and associated nerves.

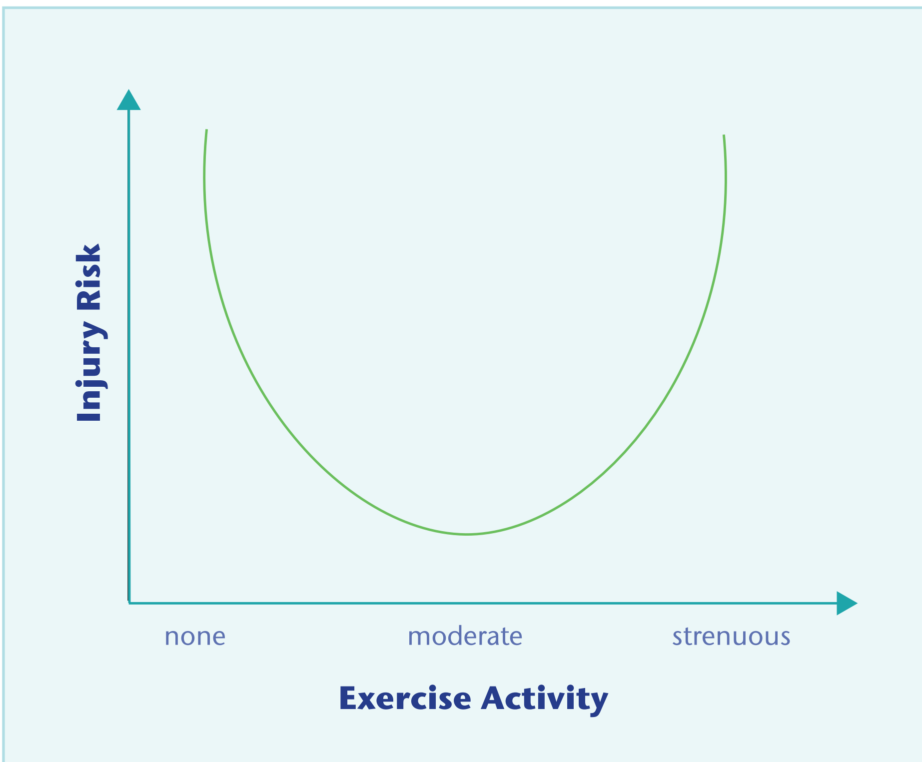



**Figure I.2. Relationship between injury risk and exercise.** This hypothetical model indicates a steep increase in risk with no exercise and with strenuous activity. (Adapted from Campello et al., Scand J Med Sci Sports, 1996)

# FINAL THOUGHTS

Trainers and health-care professionals are continually reminded of the astounding complexity of human movement. The more we learn, through newly published research and the **empirical evidence** of our own practice, the more we appreciate how much we still do not know. A corrective exercise course cannot possibly cover every movement dysfunction within the human body. However, you will learn how to identify and correct the *most common* dysfunctions, the ones you're most likely to see in clients from all walks of life. These issues include problems in the feet, ankles, knees, hips, spine, shoulders, and neck. The goal is to restore your clients' **functional**, pain-free **movement** patterns and, by extension, their **quality of life.**

**Empirical evidence:** The knowledge a person acquires through observation and experience.

**Functional movement:** A movement that is useful for its intended purpose.

**Quality of life:** The general well-being of an individual.

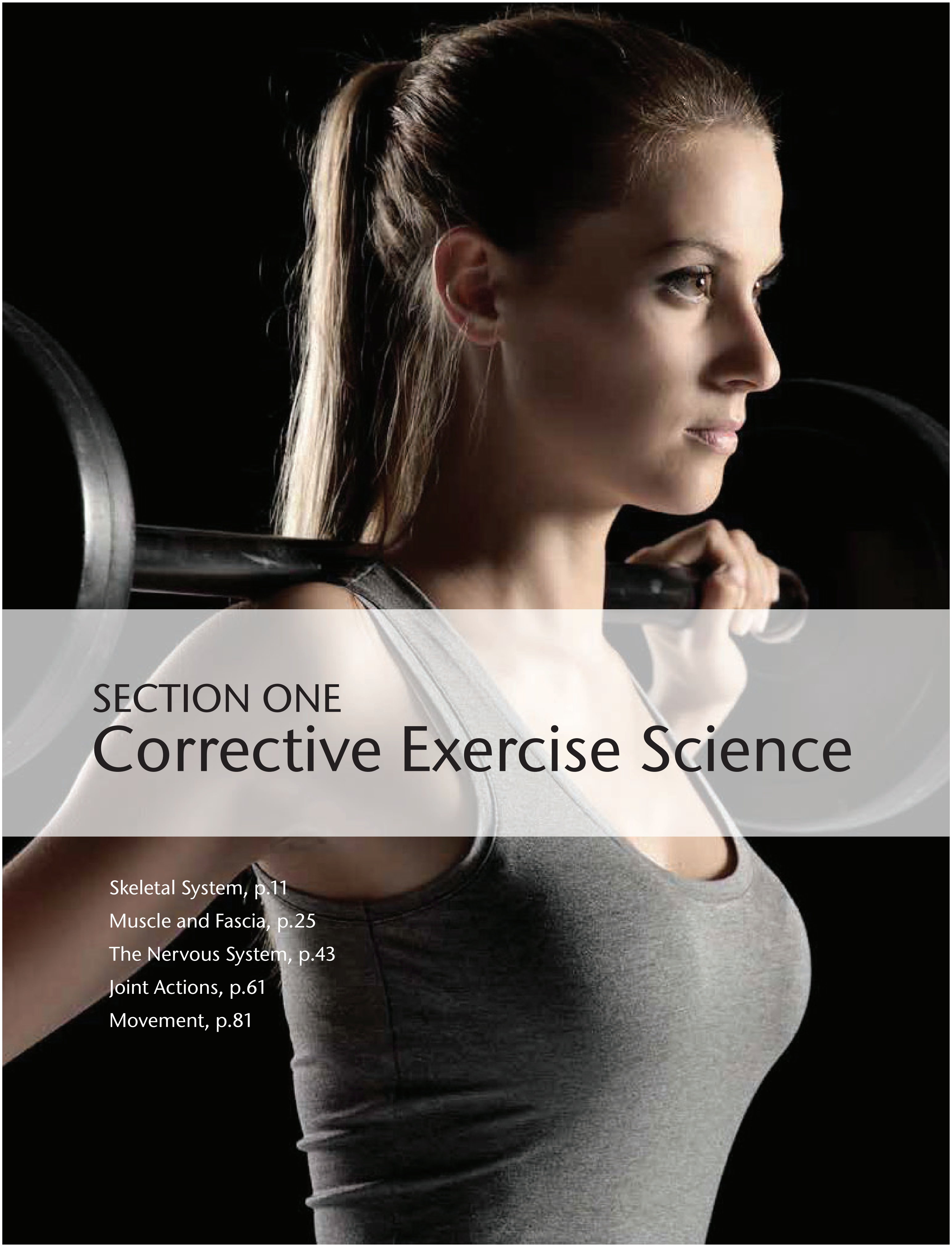
This brings us back to where we started this introduction. Your clients live in a world that discourages movement and encourages poor posture. But when they do decide to move, they often engage in popular but ill-advised exercise programs that include high-intensity exercises and training systems far beyond their current fitness level and movement competency.

In reality, if you're a personal trainer, the vast majority of people you work with will have some type of movement dysfunction. The problem could be caused by weakness, stiffness, poor motor control, or any combination of the three. That's why you need to learn and develop the skills necessary to identify and correct these issues.

Research supports corrective exercise as an effective alternative to surgery for correcting movement-related problems. In fact, sometimes participating in a corrective exercise program is more effective. Even if you aren't qualified to perform hands-on treatments, the information in this course will provide you with many of the same tools used by the world's most successful rehabilitation professionals.

## Summary

1. These days, people are more sedentary than ever and often perform activities that encourage poor posture.
2. When people do exercise, it's common for them to perform workouts beyond their functional capacity.
3. Movement and postural dysfunctions are more common than in the past.
4. The quality of movement is affected by stability, mobility, posture, and motor control.
5. Certified personal trainers will often encounter clients who possess one or more physical dysfunctions that can be corrected without the intervention of a health-care professional.
6. Corrective exercise strives to improve performance, restore performance, and reduce the risk of injury.
7. Recent research indicates that performing challenging movements and exercises can change the brain and other nervous system structures.



SECTION ONE

# Corrective Exercise Science

**TOPICS COVERED IN THIS UNIT**



**UNIT 1**

# SKELETAL SYSTEM

### What You'll Learn

In this unit, you'll receive an overview of the human skeletal system, how it's designed, and how it functions. This structure is important to understand because it forms the framework of your body. You'll learn how the functions of the skeletal system work together and how they can compete with one another. Additionally, you'll learn how the bones and tissues that make up the skeletal system can grow, repair and remodel. Finally, we'll wrap up the unit by covering the major joints within the body that can become problematic in active individuals. Therefore, at the close of this unit, you should understand how the skeletal system functions for movement, protection, and health.

# THE HUMAN SKELETON

The framework of the body is made up of 206 bones, associated cartilages and joints that form the human skeleton. It is easy to think of bone as a relatively lifeless tissue, but that's not the case. The skeleton is a living **organ system** that can grow, repair and remodel.

**Organ system:** A group of organs and tissues working together to perform specific functions.

## SKELETAL FUNCTION

The skeletal system serves many roles that we require for optimum health, movement and protection. The skeletal system has five primary functions.

- **Movement:** Bones come together to form joints that allow motion.
- **Structure/support:** The skeleton provides the structure and support we need for movement. This is one factor that separates humans from amoeba or jellyfish.
- **Protection:** Our essential organs such as the brain, spinal cord, heart and lungs are protected by the skeleton.
- **Calcium storehouse:** Calcium and other minerals are stored within bone.
- **Blood cell production:** Marrow within bone produces blood.

Importantly, these five functions compete with one another. For example, movement is best accomplished with a lighter skeleton; however, for bones to be strong they must also be relatively heavy. If calcium is taken out of bone to provide nutrients to the nervous system or muscles, bones can become weaker and reduce the protective role the skeleton must play. Nevertheless, the bones that form the skeletal system can adapt to those competing demands.

**Figure 1.1. Skeletal system of the human body.** The front and back of the human skeleton with the left side showing fibrous capsules between joints.

## SKELETAL STRUCTURE

The bones that make up the human framework can be divided into the **axial skeleton** and **appendicular skeleton**. The axial skeleton is comprised of 80 bones from the skull, vertebral column, ribcage, sternum and sacrum. The remaining 126 bones of the upper and lower extremities form the appendicular skeleton.

**Axial skeleton:** The bones of the skull, vertebral column, sternum, ribcage and sacrum.

**Appendicular skeleton:** The bones of the upper and lower extremities.

The size and shape of human bones can vary greatly, depending on role they play. The largest bone in the body is the femur and it's approximately 18.9 inches long and 0.92 inches in diameter in an average male. The smallest bone is the stapes, located within the ear, and it's approximately 3 × 2.5 millimeters. Based on their shape, bones are classified as long, flat, short, irregular or sesamoid.

The vertebral column, sometimes referred to as the spinal column, is an especially important structure within the skeletal system. It consists of five regions, if we picture it from the base of your skull down to the tailbone. The cervical region is made up of 7 vertebrae, the thoracic region is 12 vertebrae, and the lumbar region is 5 vertebrae. The sacrum consists of 5 vertebrae, and the coccyx has 4; however, these vertebrae are fused together and don't move. That means the vertebral column is composed of 33 vertebrae, but only 24 can move independently ranging from the first cervical vertebrae down to the last lumbar vertebrae. Movement between vertebrae is made possible by facet joints, which are the spaces between the bony protrusions of two adjacent vertebrae.

## BONE FUNCTION

If you've ever held a human bone in your hand in anatomy class, you might think that bones are generally light, brittle and easy to break. However, bones within a living human are heavier, stronger and more durable. That's because living bones are full of vessels and nutrients that make them adaptable organs capable of growth, repair and remodeling. In this section we'll cover each of those functions.

### Growth

**Ossification:** The hardening process of bones during development.

All bones are in the form of cartilage before birth. After a person is born, and throughout development, the softer cartilage is slowly replaced by harder bone through a processed called **ossification.** Therefore, because adolescents have softer bones, it's more difficult for a four-year old to break a bone than it is for an adult. This hardening process continues until a person reaches full development at 18-25 years.

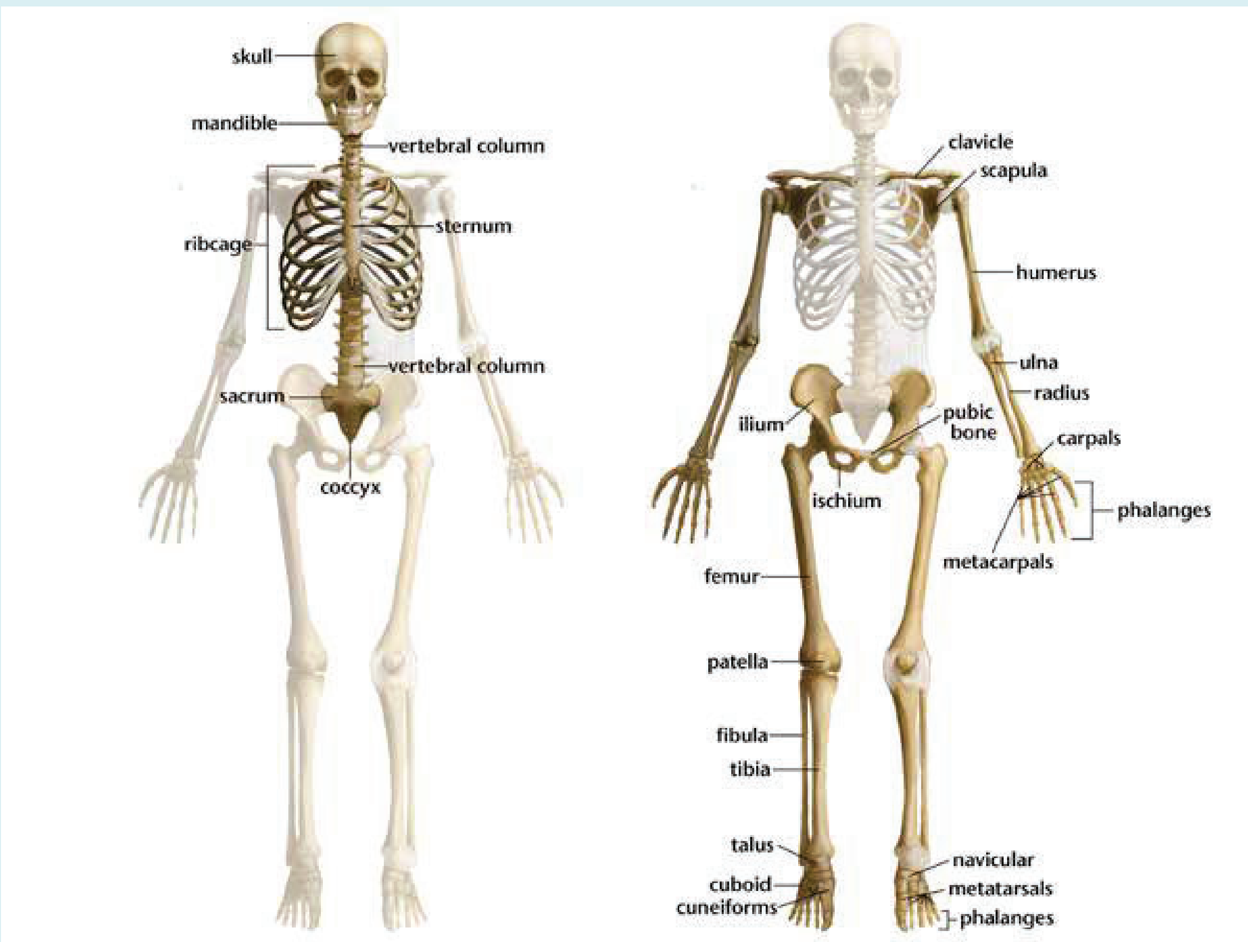



**Figure 1.2. Axial skeleton and appendicular skeleton.** A) Axial skeleton and B) Appendicular skeleton.

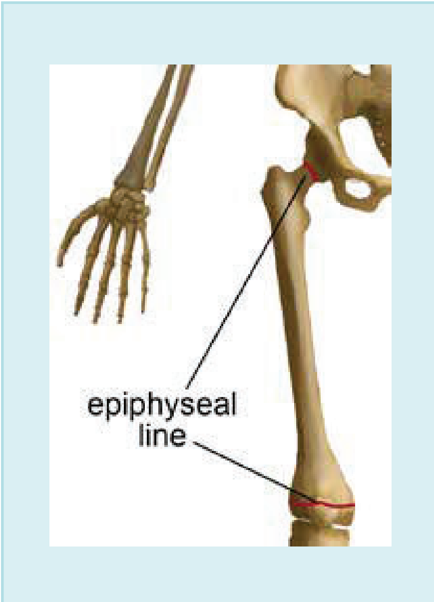



Figure 1.3. Epiphyseal line. The two epiphyseal lines of the right femur are shown. The epiphyseal line closes in adulthood and prevents the bone from elongating.

Bones not only get harder during development, they also grow longer. The length of bone increases at the **epiphyseal plate** where cartilage cells divide and push the newly formed cells toward the shaft of the bone. Eventually, the cartilage cells become mature bone cells to increase the bone's length. After a person reaches adulthood, the epiphyseal plate closes and forms an **epiphyseal line.** At this point, it's not possible for the bone to grow longer. Each long bone (a bone that is longer than it is wide) within the appendicular skeleton has an epiphyseal line at each end

**Epiphyseal plate:** The location of bone growth near the end of immature bones.

**Epiphyseal line:** A line of cartilage near the end of mature long bones.

## Repair

Bones can repair various types of damage, whether that damage is from a severe break (macrodamage) or mild tears within a bone's matrix that can't be felt (microdamage).

When a bone breaks into two or more pieces, the painful macrodamage often requires a medical intervention with a cast or screws that allow the bone to heal back to its original form. The healing process takes anywhere from 1 to 3 months, depending on the location of the break and the amount of blood supply it receives. In many cases, a broken bone can heal stronger than it was before the break because the body will produce extra bone at the site of damage.

Microdamage results from microscopic tears within the bone's matrix. It occurs as a normal daily process during activities such as walking, running, or lifting weights. All bone is replaced every few years from the accumulation of the microdamage and repair process.

Normally, microdamage isn't felt. However, when people drastically increase their activity levels to the point where the balance between microdamage and repair can't be maintained, a **stress fracture** can occur. Because most stress fractures can't be seen with a normal X-ray, a computed tomography (CT) scan is usually required to confirm the diagnosis.

**Stress fracture:** A thin bone crack due to an accumulation of microdamage.

## Remodeling

When a bone changes shape it's known as **remodeling**. Bone can grow or shrink depending on the stress, or lack of stress, that's placed on it. For example, when a person lifts relatively heavy weights, the body responds by laying down extra bone to thicken the diameter in a process called **deposition.** On the other hand, if a person is bedridden or paralyzed the body can decrease the bone's diameter through **resorption.** This theory of bone adaptation is known as **Wolff's Law.**

**Remodeling:** When a bone changes shape either by increasing or decreasing its diameter.

**Deposition:** Adding new bone with osteoblasts.

**Resorption:** Removing bone with osteoclasts.

**Wolff's Law:** A theory developed by German surgeon, Julis Wolff, which states that bone will adapt to the loads placed upon it.

**TRAIN YOUR BRAIN:** Can a poor diet weaken your bones?

Absolutely. Bones are living tissues that require nutrients for growth and maintenance. Therefore, a diet that's deficient in protein, vitamin C, calcium, or vitamin D can all weaken the bones and potentially lead to disease. Rickets is a bone disease that occurs from a Vitamin D deficiency.

**Osteoclasts:** Cells responsible for bone resorption.

**Osteoblasts:** Cells responsible for bone deposition.

**Osteocytes:** Mature bone cells that maintain a bone's matrix.

Bones rely on three cell types during remodeling. After bone is damaged, **osteoclasts** chew up the impaired bone tissue (resorption). Importantly, osteoclasts are also responsible for the loss of bone when a person is inactive due to injury or disease. Next, if there's a stimulus for growth, **osteoblasts** come into play and lay down new bone (deposition). Finally, these osteoblasts transform into **osteocytes**, or mature bone cells.

Importantly, bone remodeling occurs throughout life. When a person is younger, remodeling happens at a faster rate. As a person grows older, the remodeling process typically slows, but continues nonetheless.

## BONE STRUCTURE

**Periosteum:** The outer covering of bone where osteoblasts are located.

**Endosteum:** Connective tissue that covers the inside of bone and medullary cavity.

**Medullary cavity:** Central cavity of the bone shaft where marrow is stored.

**Compact bone:** Hard outer layer of dense bone tissue.

**Spongy bone:** Porous, light inner layer of bone tissue.

**Osteoporosis:** Bone disease characterized by a loss in bone mass and density.

Bones are rich with blood vessels, cells, and nerves that allow it to perform the functions we just covered. The **periosteum** and **endosteum** are connective tissues that cover long bones and they contain the cells responsible for growth, repair, and remodeling. The periosteum covers the outside of bones while the endosteum covers the inner lining of bones and the **medullary cavity**.

Before we discuss blood supply and nerves, let's go over the two primary types of bone tissue. The structure of bone is not a uniformly hard material as it might seem if you held it in your hand. Indeed, bone consists of two different materials: the outer layer of compact bone and inner portion of spongy bone.

- **Compact (cortical) bone:** This hard outer layer of dense tissue is strong, solid, and resistant to bending. Approximately 80% of a person's skeletal mass comes from compact bone.
- **Spongy (trabecular or cancellous) bone:** Light, porous inner bone material that forms a latticework of bony structures called trabeculae. **Osteoporosis** mainly affects spongy bone.

The combination of compact and spongy materials is what gives bone its strength while still being relatively lightweight. If bones were made entirely of compact material, they would be too heavy for efficient movement. And spongy bone alone wouldn't give bones the strength they need.

## Bony Protrusions

Various **bony protrusions** throughout the skeleton contribute to each bone's unique shape. For example, the head of the femur contains two primary protrusions: greater trochanter and lesser trochanter. A trochanter, or protrusion, is the site of muscle attachment. The anatomical purposes of areas of bone swelling are to strengthen the bone in that region and provide a greater contact surface for the muscles to attach.

Throughout the skeleton, these areas of increased bone formation go by different names depending on the bone on which they reside. For example, the upper humerus has two protrusions, greater tuberosity and lesser tuberosity, that serve as attachment points for the rotator cuff muscles. At the lower aspect of the humerus, the protrusions by the elbow are called epicondyles. Moving further down the body, the protrusions of the upper femur are known as trochanters.

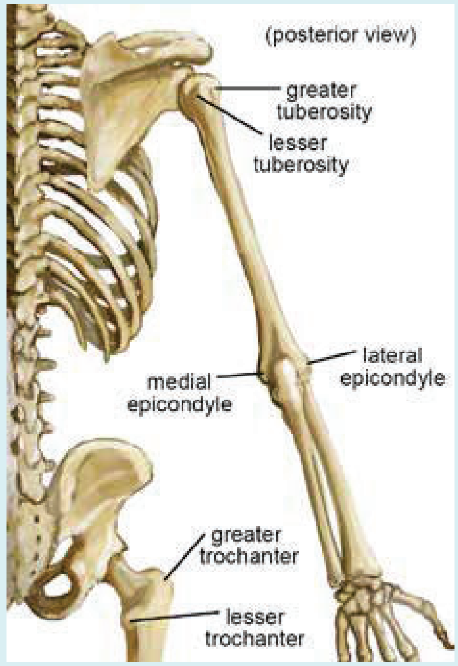



**Figure 1.4.** Bony protrusions. Various areas of increased bone formation that provide stronger, larger attachment points for muscles.

**Bony protrusion:** An eminence on the surface of bones that increase strength and contact area for muscle attachments.

## Blood and Nerve Supply

Even though bones are not actively growing longer in adults, they still require a constant blood supply. Bone receives its blood from three sources: periosteal vessels, nutrient arteries, and epiphyseal vessels. These three vessels ensure that blood is available to all areas of the bone, from the innermost spongy bone to the outer compact bone.

The functional unit of compact bone consists of **osteons (Haversian systems)**. These vertically stacked units each contain a nerve and one or two blood vessels.

**Trabeculae** are functional units of spongy bone that consist of a network of plates and rods. Because spongy bone is less dense than compact bone, it contains a richer source of blood vessels.

Not only do bones have a rich blood supply, they can also sense pain. One primary source of bone pain is from the periosteum, the outer covering of bone that contains pain- sensitive nerve endings. Therefore, we'll now discuss the important connective tissue within joints that diminish the pain signal.

**Osteons (Haversian systems):** Functional units of compact bone.

**Trabeculae:** Functional units of spongy bone.

## Cartilage Structure and Function

Articular cartilage is a connective tissue covering at the end of long bones that provides smooth bone contact in freely moving joints. When the cartilage is degraded or lost from overuse or aging, bone-on-bone contact results in pain and stiffness at the joint. Because **osteoarthritis** is a common problem with athletes and older populations, a thorough understanding of the structure and function of cartilage is important for any trainer or therapist.

**Osteoarthritis:** Bone-on-bone contact that results in joint pain and stiffness due to a loss of articular cartilage.

**Nociceptors:** Pain sensitive nerve endings.

As mentioned earlier, bones can sense pain. The periosteum and endosteum coverings of bone contain pain sensitive nerve endings called **nociceptors**. Because joint motion shouldn't be painful, articular cartilage covers the ends of moving bones to block the pain signal and reduce compressive stress.

Importantly, articular cartilage is just one form of cartilage in the skeletal system. Collectively, cartilage is a type of connective tissue made up of dense collagen fibers embedded in a firm, gelatinous substance that gives it the consistency of plastic to provide tensile strength while still being more pliable than bone. Let's cover the three types of cartilage.

- **Hyaline cartilage:** This deformable but elastic type of cartilage is the most widespread form in the body. It's located in the nose, trachea, larynx, bronchi; at the end ribs, and at the end of bones of many freely moving joints in the form of articular cartilage.
- **Fibrocartilage:** This tough tissue is located in the intervertebral discs and at the insertions of tendons and ligaments.
- **Elastic cartilage:** As the name implies, this is the most pliable form of cartilage. It gives shape to the external ear, the auditory tube of the middle ear and the epiglottis.

In addition to being a barrier to pain, cartilage also plays an important role in bone development. Indeed, most bones begin as cartilage, and then the cartilage ossifies as you age to become the hardest connective tissue in the body. A newborn baby has the softest bones since it contains the greatest percentage of cartilage. Throughout development, the bones become progressively harder as cartilage is replaced with bone. Once a person reaches full development, the only remaining cartilage in bone is articular cartilage to protect bone-on-bone contact, along with an epiphyseal line near the joint.

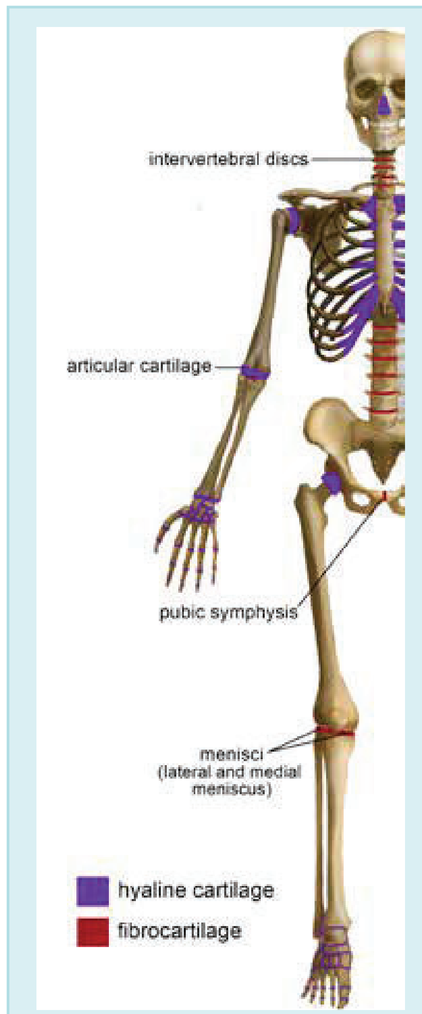



**Figure 1.5. Hyaline and fibrocartilage.**

However, not all cartilage is gone by the time a person reaches adulthood. Indeed, cartilage is part of the adult skeleton and it provides important roles at specific joints. For example, the knee joint contains hyaline cartilage to protect against painful bone-on-bone contact. Unlike bone, cartilage doesn't contain pain-signaling nerve endings. And since hyaline cartilage is deformable, it reduces compressive stress at the joint.

When the hyaline cartilage is lost from aging, compressive stress, or disease, the joint space narrows and unprotected bones can contact each other. Osteoarthritis occurs when the loss of cartilage in the joint spaces results in pain and stiffness from bone-on-bone contact. It most commonly occurs in the knees, hands, hips, and spine. Unlike other types of tissues, cartilage doesn't have its own blood supply. Therefore, it's very slow to heal and the body usually can't replace it when it's lost.

Now that we've covered the skeleton, bones, and cartilage, let's finish with the connective tissue that holds it all together: ligaments.

## LIGAMENT STRUCTURE AND FUNCTION

Ligaments are 70% water with the remaining 30% made-up of dense, fibrous collagenous tissue. The strength of a ligament is primarily derived from type I collagen fibers that resist strain. Ligaments also possess a little bit of **elastin**, an important elastic protein found in all connective tissue that allows those tissues to regain its original shape.

Without elastin, all connective tissues would stay deformed after being stretched. Skin also contains elastin, which allows it to bounce back after you pinch it.

If you've ever sprained your ankle, you unintentionally learned the important role that ligaments play. When an unexpected movement results in torques that are beyond a ligament's tensile strength, damage ensues. Nevertheless, the roles of ligaments go beyond resisting damage. Ligaments are responsible for attaching bone to bone, passively stabilizing and guiding a joint, resisting excess movement at a joint and allowing the brain to sense the position of the joint in space (covered in Unit 4).

**Elastin:** An elastic protein found in connective tissue that gives the tissue extensibility.

**Varus:** An abnormal joint movement away from the midline of the body. At the knee joint, varus can result in "bow-leggedness."

**Joint capsule:** A thin, strong layer of connective tissue that contains synovial fluid in freely moving joints.

**Valgus**: An abnormal joint movement toward the midline of the body. At the knee joint, valgus can result in "knock knees."

The location of a ligament can be extrinsic, intrinsic or capsular with respect to the joints. As the knee joint contains all three types of ligaments, let's go over each form and how each contribute to knee function.

- **Extrinsic ligament:** This type of ligament is located on the outside of the joint. An example is the lateral collateral ligament (LCL) on the lateral side of the knee to resist **varus** stress.
- **Intrinsic ligament:** This ligament is located inside the joint. The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are situated inside the knee joint to resist anterior and posterior movement of the tibia, respectively.
- **Capsular ligament**: This type of ligament is continuous with the **joint capsule.** The medial collateral ligament (MCL) is a capsular ligament that resists **valgus** stress at the knee by keeping the joint approximated.

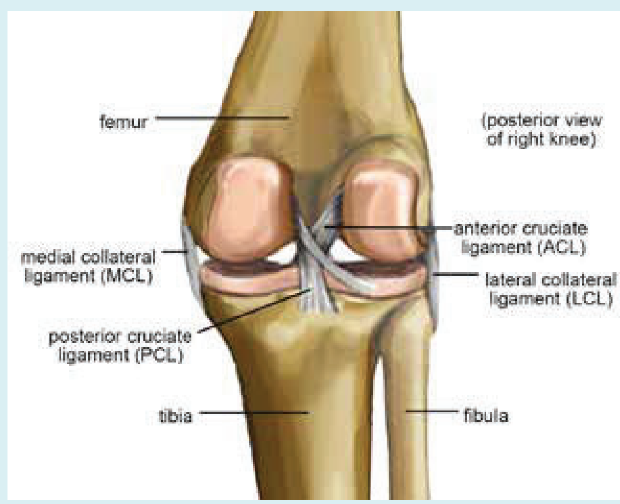



**Figure 1.6. Ligaments of the right knee joint.** The knee joint contains three types of ligaments: extrinsic (LCL), intrinsic (ACL, PCL) and capsular (MCL).

**TRAIN YOUR BRAIN:**
Will weight training stunt a child's growth?

According to George Salem, Ph.D., associate professor at the University of Southern California's Division for Biokinesiology and Physical Therapy, "There's absolutely no evidence that weight training will stunt a child's growth. When you see short athletes in gymnastics or weight training, it's due to genetics." In other words, the young athletes who grew taller didn't make the cut.

Importantly, ligaments aren't just passive tissues that only resist strain. Indeed, part of their function is driven by nerve innervation. The ligaments within your joints are connected to the central nervous system (CNS) through reflex pathways to communicate strain to guard against injury. And during movement, the free nerve endings detect joint position, speed and direction as part of the proprioceptive sensory feedback circuit.

## LIGAMENT CREEP, LAXITY AND TEARS

**Creep:** A temporary deformation of connective tissue.

**Laxity:** A permanent deformation of connective tissue caused by excessive stretching.

**Tear:** A partial or complete separation of a tissue due to a stretch beyond its structural capacity.

A ligament is a viscoelastic material that can return to its original shape when stretched. This allows the ligament to **creep**, a temporary stretch that isn't harmful. For example, if you bend over to touch your toes, ligaments within the spinal column will stretch. And when you stand up, the ligaments shorten and return to their original shape.

However, like all tissues in the body, ligaments have a limit to how much they can stretch before damage occurs. When a ligament is stretched beyond its structural and functional ability, it can develop **laxity** or **tear**.

Laxity is a permanent structural deformation due to frequent stretching of a tissue at its end-range of elasticity. Think of a rubber band that's constantly over-stretched.

Eventually that rubber band will take on a new, longer shape compared to its original form. When a ligament has laxity, the joint becomes less stable (i.e., loose) and makes a person more susceptible to joint dislocations and osteoarthritis.

A tear occurs when a tissue is stretched beyond its structural capacity. The tear can be either partial or complete. A partial ligament tear can heal with rest, whereas a complete tear usually requires surgery to repair. Ligaments have a limited capacity to heal due to their low blood supply. Indeed, blood flow to ligaments is less than that of muscle or bone, which is why it can take months or a year to completely heal.

## JOINT CAPSULE

**Synovial membrane:** A thin layer of connective tissue beneath the joint capsule that makes a lubricating fluid.

A joint capsule is a thin, strong layer of connective tissue that surrounds freely moving joints. Its strength primarily comes from type I collagen fibers, as is also the case with ligaments. Directly beneath the joint capsule is a thin layer of **synovial membrane** that lubricates the joint and reduces friction during movement.

Much like the ligaments we just covered, joint capsules also resist excess tension at the joints. Importantly, joint capsules are innervated by nerves. Therefore, they can trigger reflex contractions of the surrounding muscles to protect the joint from damage.

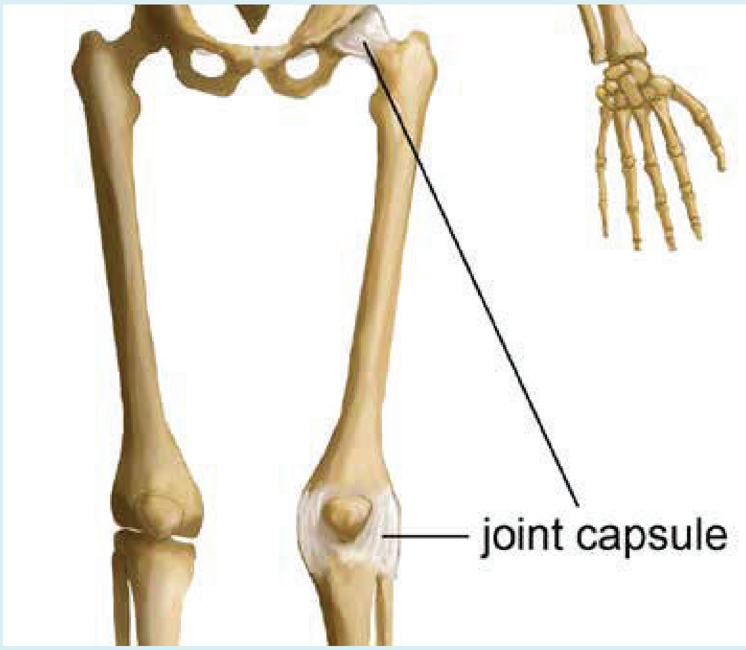



**Figure 1.7. Joint capsule.** The joint capsule at the left hip and knee.

**TRAIN YOUR BRAIN:** Think like a physical therapist.

What's the number one risk factor for injury to any joint? A previous injury to that joint. This fact is especially true for the ligaments as they have a limited capacity to recover.

When a ligament heals from a partial or complete tear, the tissues aren't as strong as they originally were due to an accumulation of scar tissue. Because scar tissue consists of abnormal collagen, poor cross-linking, and smaller fibrils, it's a weaker form of connective tissue. This means the ligament is more susceptible to future tears. Therefore, extra care should be taken when stretching or training a joint that endured a ligament injury.

And joint laxity caused by an overly stretched ligament can make a joint less stable than it needs to be. Unfortunately, a loose ligament cannot regain its original shape and become "tight" again. Therefore, muscles that surround a loose joint should be sufficiently strong as they must also provide the stabilizing effect the loose ligament can no longer perform.

# JOINTS

The human body has 360 joints; however, for the purposes of this course there are only 16 that we'll need to cover. These 16 joints are emphasized because they're the most problematic areas of articulation for most active individuals. Throughout this course we'll spend much more time covering the actions and functions of these joints. But for now, we'll start with the names and locations of the 16 joints.

Table 1.1

| Joint | Area of Articulation |
|---|---|
| sternoclavicular (SC) | sternum and clavicle |
| acromioclavicular (AC) | acromion process (scapula) and clavicle |
| glenohumeral (GH) | glenoid fossa (scapula) and humerus |
| scapulothoracic region (pseudo joint) | scapula and ribcage |
| humeroradial | humerus and radius |
| humeroulnar | humerus and ulna |
| radioulnar (proximal) | radius and ulna (elbow region) |
| radioulnar (distal) | radius and ulna (wrist region) |
| radiocarpal | Radius and carpal bones |
| sacroiliac (SI) | sacrum and ilium |
| hip | femur and pelvis |
| patellofemoral | patella and femur |
| tibiofemoral | tibia and femur |
| tibiofibular | tibia and fibula |
| talocrural | talus and tibia |
| subtalar | talus and calcaneus |

**TRAIN YOUR BRAIN:** What does it mean to be double-jointed?

Ligaments are normally very taut around a joint. However, some people are born with "loose ligaments" that allow the joints to move through a greater range of motion than is normal. Even though it might seem cool to have excessive flexibility and appear "double-jointed," loose ligaments make people more susceptible to joint dislocations and osteoarthritis.

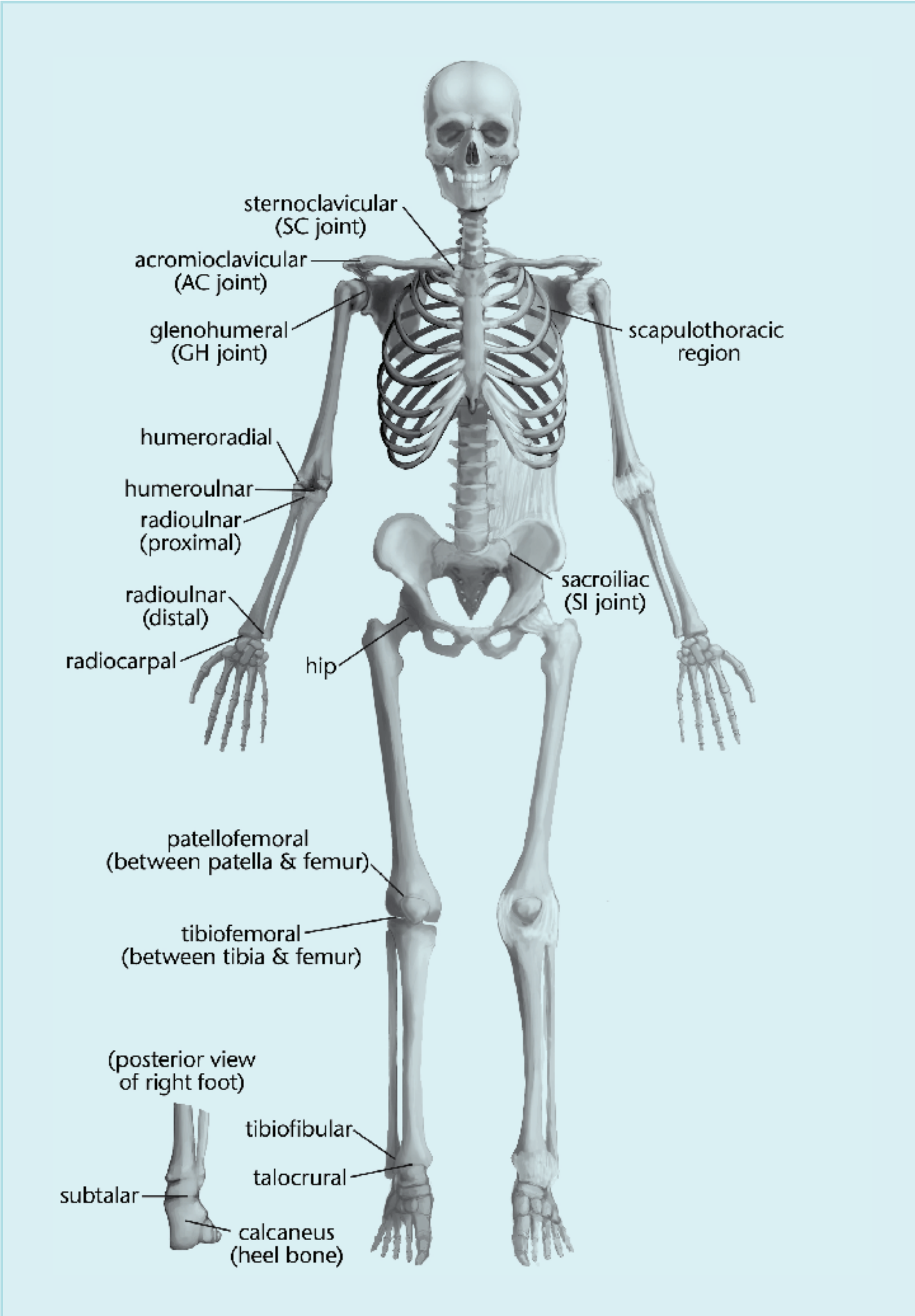



**Figure 1.8. Primary joints of the body.** The figure depicts the most common joints that can become problematic in active people.

As this unit ends and we've reviewed the structure and function of the skeletal system, it's important to keep in mind the context of this information. The physiology of bone and connective tissue is an essential part of the human body's framework so it can move, grow, adapt and remodel. However, those structures can also be limiting factors.

Therefore, all the connective tissue components covered in this unit should be considered when you assess clients who demonstrate movement limitations and joint pain.

## Summary

1. The human skeleton is made up of 206 bones that can be divided into the axial and appendicular skeletons.
2. There are five functions of the skeletal system: movement, structure/support, protection, calcium storehouse and blood cell production.
3. Bones that make up the skeleton are living, adaptable tissues that can grow, repair, and remodel.
4. Bones can be either compact or spongy, and the combination makes the skeleton both strong and lightweight. The functional units of compact bone are osteons; the functional units of spongy bone are trabeculae.
5. Three types of cartilage help support and protect bones: hyaline cartilage, fibro-cartilage and elastic cartilage.
6. Ligaments are dense, collagenous tissues that hold bones together and resist tensile stress.
7. The joint capsule is a fibrous connective tissue that surrounds articulating joints and resists compressive stress.

## TOPICS COVERED IN THIS UNIT



UNIT 2

# MUSCLE AND FASCIA

## What You'll Learn

In this unit, you'll receive an overview of the muscular system, how it's designed, and how it functions. The muscular system provides the contractile forces that create movement at the joints we covered in Unit 1. You'll learn the structure and function of muscles along with their attachments. Then you will become educated about the importance of fascia and how it connects seemingly unrelated joints together. Finally, you'll learn the origins and insertions of the muscles that move all the major joints in the body. Therefore, at the close of this unit, you should understand how the muscular system functions to drive movement.

**Cardiac muscle:** A type of muscle tissue found only in the heart, responsible for pumping blood throughout the body.

**Smooth muscle:** A type of muscle tissue that moves internal organs, such as the bowels, and vessels, such as the artery walls.

**Skeletal muscle:** The contractile tissue that produces force in the human body.

**Origin:** The attachment of a muscle closest to the head when viewed from the anatomical position.

# THE MUSCULAR SYSTEM

The muscular system is made up of approximately 650 muscles, depending on the source cited. The stapedius is the smallest muscle in the body, which makes sense because it's attached to the stapes, the smallest bone in the body. The gluteus maximus is the largest muscle, and not surprisingly, it's also connected to the largest bone: the femur.

Muscles are categorized under three primary types: cardiac, smooth and skeletal. **Cardiac muscle** makes up the walls of the heart to make it contract. **Smooth muscle** is located throughout the body in regions such as the walls of the intestines, uterus, blood vessels and inner eye. **Skeletal muscle** is the contractile tissue that drives and controls movement.

Because this course is primarily about movement, the information in this unit will pertain to the actions of skeletal muscle. Therefore, for the remainder of this unit the word "muscle" will relate specifically to "skeletal muscle."

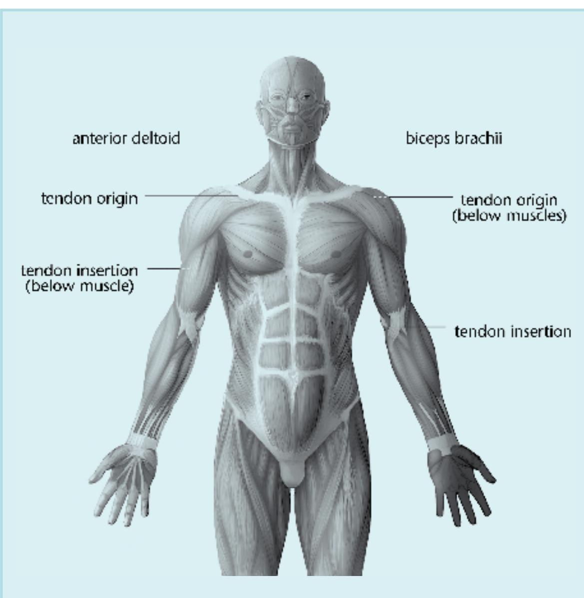



**Figure 2.1. Origin and insertion.** The origin and insertion points for the anterior deltoid and biceps brachii. From the anatomical position as shown, the origin is closer to the head; the insertion is closer to the feet.

## MUSCLE ATTACHMENTS

Virtually every muscle in the body has two attachment points that correspond to two different bones. The locations of the attachment points are described as an **origin** and **insertion**. When a person is standing in the anatomical position (arms hanging at the sides and palms facing forward), the origin is the muscle attachment closest the head, and insertion is the attachment closest to the feet. Each origin and insertion end of a muscle belly connects to its respective bone through a **tendon**.

### Tendon Structure and Function

The primary function of a tendon is to transfer force between activated muscle and the bone where it inserts. The structure of tendons is formed from dense connective tissue formed by an abundance of **type I collagen** fibers that provide strength.

Tendons are similar to ligaments and joint capsules because they all have a limited blood supply and low metabolism. Nevertheless, the metabolism within a tendon can increase when it's physically loaded during movement and resistance training. That is one of the reasons why doctors now recommend exercise sooner rather than later after an injury.

## Skeletal Muscle Structure and Function

For muscle to jump into action, it must be activated by the nervous system, as we'll cover in Unit 4. For now, what's important to understand is the effect that muscle activation has on a joint. A joint can either move (i.e., rotate around its axis) or remain static, depending on how much force the muscle produces. We'll start by covering the functional units that allow a muscle to contract and then discuss the muscle and joint interaction.

Skeletal muscle is made up of bundles of muscle fibers. Each bundle is a fascicle and is covered by a layer of connective tissue called perimysium. Within the fascicle is a collection of muscle fibers, and each muscle fiber is made up of smaller myofibrils.

The myofibril contains **sarcomeres**, the functional units that can make the muscle fiber shorten. Sarcomeres are lined up in series within the myofibril to form a rod-like structure. In other words, if the myofibril were a yardstick, the sarcomeres would be the inch markers. Each sarcomere can shorten only a miniscule distance; however, the combined effect of all sarcomeres shortening at the same time causes the entire muscle to significantly shorten.

The sarcomeres shorten due to sliding of myosin and actin past one another. Importantly, this process can't occur in the reverse order. In other words, when a muscle is activated, it can only shorten—or more specifically—attempt to shorten, as we'll discuss next.

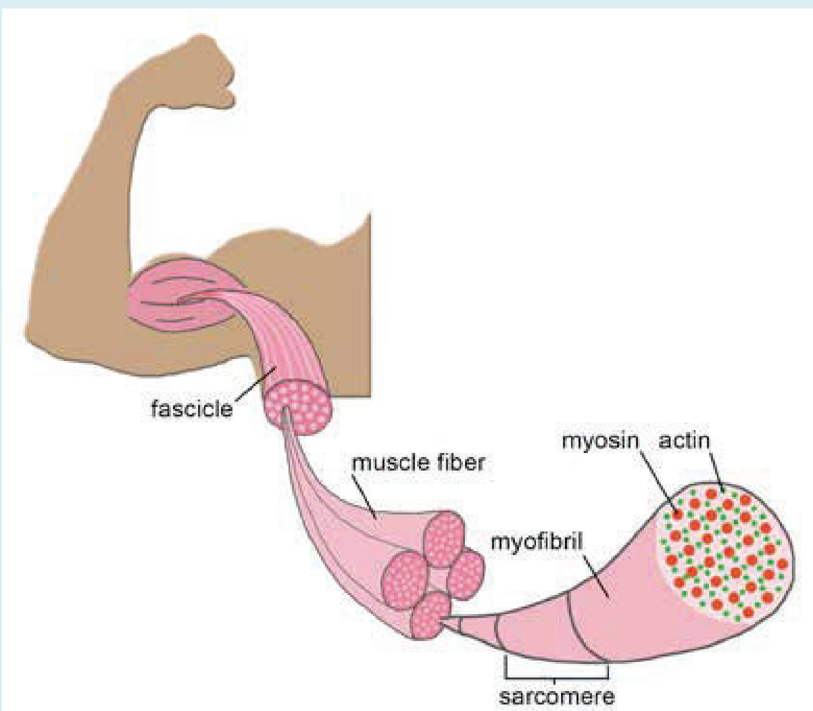



**Figure 2.2. Skeletal muscle.** Structural and functional components of muscle.

**Insertion:** The attachment of a muscle closest to the feet when viewed from the anatomical position.

**Tendon:** A strong connective tissue made primarily of collagen that connects muscle to bone.

**Type I collagen:** A structural protein contained within a tendon. Fascicle: A bundle of muscle fibers contained within a skeletal muscle. Myofibril: A rod-like unit of a muscle cell made up of sarcomeres.

**Sarcomere:** The functional unit of a skeletal muscle fiber. Myosin: The thick myofilament contained within a sarcomere. Actin: The thin myofilament contained within a sarcomere.

## MUSCLE ACTIONS

As we just covered, when a muscle is activated it is only capable of shortening. But there are times when a muscle could lengthen, or remain in a static position, even though the muscle fibers are attempting to shorten. It is common for people to refer to the action a muscle produces as being a "contraction"; however, the word contraction can easily create confusion because it refers to "shortening." Therefore, it's more appropriate to think of a muscle's possible functions in terms of actions, not contractions. In other words, a muscle can perform three possible actions: shorten, lengthen or remain static. Let's cover the terms used to describe each of those actions.

- **Concentric action:** when an activated muscle shortens.
- **Eccentric action:** when an activated muscle lengthens.
- **Isometric action:** when an activated muscle remains in a static position.

Whether a muscle performs a concentric, eccentric or isometric action depends on the relationship between the **pulling force** it produces and the **resistance force** it's trying to overcome.

A concentric action occurs when the pulling force a muscle generates is greater than the force applied by resistance in the opposite direction. This causes the muscle to shorten. An eccentric action occurs when the pulling force is less than the resistance force (i.e., muscle lengthens). An isometric action occurs when a muscle's pulling force equals the opposing force produced by any type of resistance (i.e., muscle length remains constant). Remember, even if a muscle action is either eccentric or isometric, the muscle fibers are attempting to shorten.Therefore, the elbow flexors will lengthen even though the brain is attempting to pull the forearm up.

Now that we've covered the three actions a muscle can produce, let's move on and discuss how muscles are categorized according to movement.

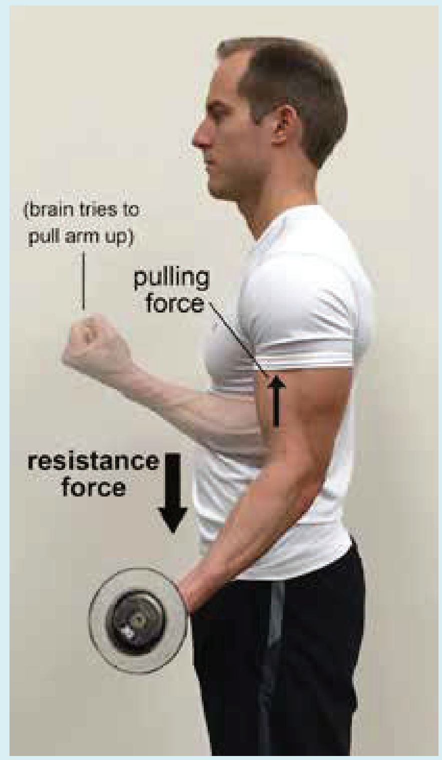



**Figure 2.3. Eccentric action of elbow flexors.** The pulling force produced by the elbow flexors is less than the downward resistance force produced by the dumbbell.

**Concentric action:** An action that occurs when an activated muscle shortens. Eccentric action: An action that occurs when an activated muscle lengthens. Isometric action: An action that occurs when an activated muscle remains in a static position.

**Pulling force:** A force a muscle produces to shorten.

**Resistance force:** An external force that opposes the force a muscle produces to shorten. Plantar fasciitis: A common cause of heel pain due to an irritation of the connective tissue on the bottom of the foot.

## THE ROLES OF MUSCLE

Most movements are driven by a collection of muscles, and each muscle is capable of playing a different role. A muscle can function as an **agonist**, **antagonist** or **synergist**, depending on the movement. Let's discuss what each of those terms mean.

**Agonist:** The muscle or muscle group most directly involved in producing a movement.

**Antagonist:** One or more muscles that have the opposite action of a specific agonist.

**Synergists:** Muscles that work together during movement.

### Agonist

An agonist is the muscle or muscle group most directly involved in producing a movement. For example, the biceps brachii is the agonist for elbow flexion. And the tibialis anterior is the agonist for dorsiflexion at the ankle.

### Antagonist

An antagonist is one or more muscles that have the opposite action of a specific agonist. Because the triceps extends the elbow joint and the biceps brachii flexes the elbow joint, the triceps is an antagonist to the biceps brachii.

### Synergists

Synergists are muscles that work together during movement. Because most movements require a contribution from many different muscles, synergistic actions are very common. For example, the biceps brachii and brachialis muscles act as synergists during elbow flexion.

Imagine curling a dumbbell with your right arm. There will be synergistic actions of the muscles that cross the wrist joint to hold it in a neutral position during the movement.

Furthermore, muscles in the shoulder joint will contract to neutralize any movement at the shoulder. Therefore, even a motion as seemingly simple as a biceps curl can require the synergistic contribution of many muscle groups.

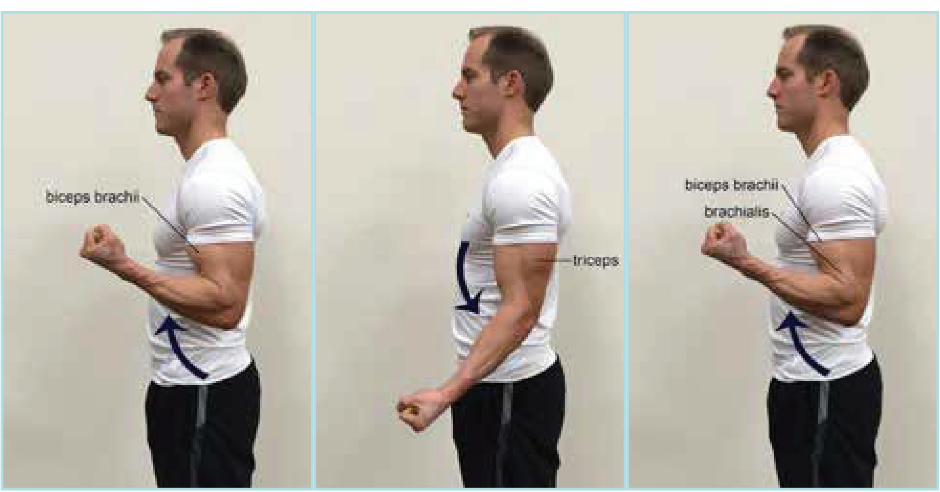



**Figure 2.4. Agonist, antagonist and synergistic actions.** A) The biceps brachii performs elbow flexion. B) The triceps perform elbow extension. Therefore, each muscle is an antagonist to the other. C) The biceps brachii and brachialis work in synergy to perform elbow flexion.

## Force-Couple

**Force-couple:** When two or more muscles concurrently produce force in different linear directions to produce one movement.

Another example of muscle synergy is a muscular **force-couple**. A force-couple occurs when two or more muscles concurrently produce force in different linear directions to produce one movement. To make a right turn on a bicycle, the right arm must pull inward as the left arm pushes outward. The force each arm produces is in a different direction; however, it results in one movement (i.e., a turn to the right).

A force-couple is required during deltoid and supraspinatus actions at the glenohumeral joint while lifting the arm out to the side. When the deltoid muscle shortens, it pulls upward on the head of the humerus. This action would normally cause the head of the humerus to compress up into the scapula if it weren't for the simultaneous inward pull from the supraspinatus.

In other words, the combined actions that produce a force-couple can allow joints to move through a greater range of motion. The force-couple between the deltoid and supraspinatus is a prime example because the coupling effect avoids impingement within the subacromial space.

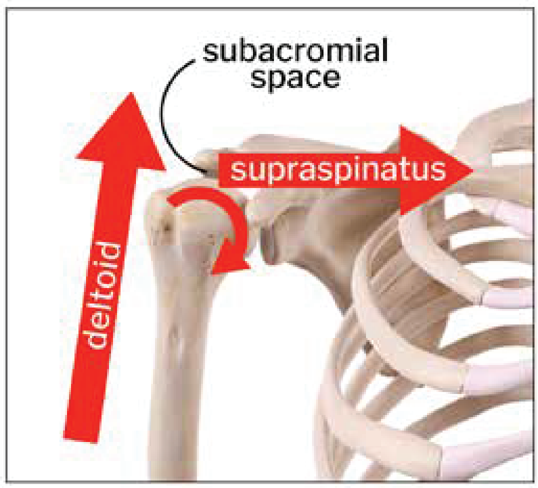



**Figure 2.5. Force-couple at the glenohumeral joint.** When the deltoid contracts it pulls the humerus upward, but the simultaneous contraction of the supraspinatus pulls the humerus inward to create a force couple. This force-couple offsets glenohumeral impingement when the arm is raised to allow the humerus to rotate and elevate without restriction.

## SKELETAL MUSCLE GROUPS

Now that we've covered the structure and function of skeletal muscle, let's take a look at the major muscle groups across the body. Because extremely small muscles throughout the face, hand and feet are mostly irrelevant to this course, they were not included in the following figures.

However, later in this unit there are tables that outline the origin and insertion for virtually every muscle group. The tables will serve as a valuable tool whenever you're unsure of a muscle's origin and insertion.