

The Foundations of Human Movement and Physical Fitness

THE FOUNDATIONS OF HUMAN MOVEMENT AND PHYSICAL FITNESS

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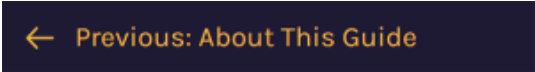
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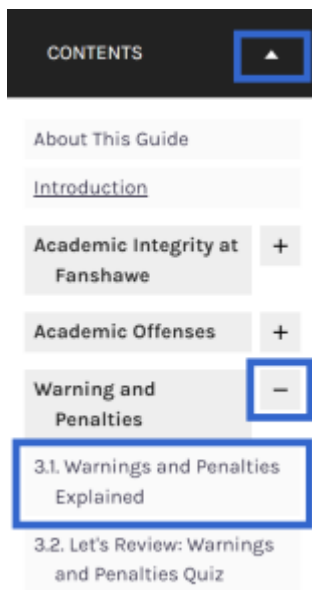
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PREFACE

Preface Outline

Origins of INDS 1120
SILEx Project

ORIGINS OF INDS 1120



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The INDS 1120 course was created by A.J. Stephen during the height of the COVID-19 pandemic. It officially launched in the Winter of 2022 and was delivered fully online with one clear goal: to make learning about movement, physical fitness, and exercise simple, fun, and easy for anyone to understand and apply to their own life.

Since then, the course has been updated and improved with help from professors Connor Dalton and Sarah Fraser, who brought new ideas and fresh energy to make the student experience even better.

This course and this textbook are designed to help you:

- Understand how the body moves
- Learn how to make lasting improvements to your fitness
- Build effective workout plans
- Explore whether a future in Kinesiology, Fitness or Health Promotion is the right fit for you

You don't need a science background or special skills to succeed in this course. All you need is curiosity, an open mind, and a willingness to learn how movement can improve health, performance, and quality of life.

SILEX PROJECT



Welcome to the Fitness Centre

Video: “Welcome to the Fitness Centre 2” by Fanshawe OER Design Studio [3:02] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

This course contains a Signature Learning Experience (SILEx) that promotes the development of four key skills essential for success after graduation:

- Novel & Adaptive Thinking
- Resilience
- Self-Directed Learning
- Implementation

By completing all aspects of this project, you will cultivate many skills and behaviours important for personal and professional growth:

- Time management
- Accountability
- Discipline
- Attention to detail
- Organization
- Resourcefulness
- Leadership
- Adaptability

The objective of this project is to set and execute a specific fitness-related plan over the course of eight weeks.

You will be encouraged to step out of your comfort zone and make notable and sustainable improvements to your physical health and fitness.

Summary of Required Submissions

1. Complete an Initial InBody Assessment
2. Set your goals
3. Create a plan (template provided on FOL)
4. Submit weekly gym attendance confirmations via password (minimum 8)
5. Provide Progress Presentation
6. Complete Final InBody Assessment and Presentation

Click on each of the accordions below to view each step in more detail:

1. Complete an Initial InBody Assignment

Schedule your InBody assessment at the Fanshawe Fitness Centre before the project start date. The assessment takes about 15 to 20 minutes and provides details related to your body composition, including:

- Body weight
- Total body water
- Body fat mass
- Percentage body fat
- Skeletal muscle mass
- Segmental lean analysis

Click on the link to view a sample InBody assessment: [InBody Result Sheet](#).

2. Set your Goal(s)

Using the results of your fitness assessment, choose two areas you want to improve. Be specific and realistic. For example: “Lose 10 pounds” or “Increase muscle mass by 5 pounds.”

If you’re not sure what is realistic based on your situation, talk to your professor or book a free consultation with the Fanshawe Fitness Centre’s staff. They’re here to help, and they get paid to do this!

Below are some examples to help guide you:

Body Composition

- Waist, hip, arm, and leg circumference increase or decrease (e.g., decrease waist circumference by 3 inches)
- Clothing size changes (e.g., large shirt size to medium shirt size)

Aerobic Fitness

- Better running/walking speed, distance or time (e.g., run 1 mile in less than ‘X’ minutes)
- Improvement in the beep test or other standardized cardio test
- Better rowing speed, distance or time

Strength & Endurance

- Improve my one rep maximum squat from 200 lbs to 240 lbs
- Perform 12 repetitions of bench press at 125 lbs
- Complete the workout “Fran” in less than 7 minutes
- Complete a 5-minute plank

Optional: You can also set a secondary goal based on something that’s important to you.

Need Help?

Book a free consultation with the Fitness Centre Staff. They are available to guide you, answer questions, and help you set realistic, achievable goals.

3. Create a Plan

Using the document provided on the FanshaweOnline (FOL) course page, create a workout plan that you will follow during the eight-week project period.

This plan must consist of at least five specific exercises which you will complete in the gym each week. Each exercise should match your current skill level and help support your goal(s).

Optional: You can add 1 to 3 extra actions outside the gym to help you succeed even more. Examples include:

- Go to bed no later than 10 pm every day
- Limit consumption of chips to 1 bag per week
- Drink a minimum of 3L of water per day
- Completely eliminate soda consumption

Once your plan is complete, submit it along with your InBody Assessment to the correct FOL submission folder before the deadline.

Want Extra Advice?

The Fanshawe Fitness Centre staff are available to help you build your plan and set realistic, achievable goals. Book a free consultation. They are paid to help you succeed!

4. Submit Weekly Gym Attendance Confirmations

Once the eight-week goal has begun, you are required to attend the Fanshawe Fitness Centre at least once a week to complete the exercises listed in your plan.

After you have finished your workout:

- Get a password from Fitness Centre Staff to confirm attendance
- Enter this password on the FOL quiz for that week

Bonus Opportunity:

You can earn bonus marks by attending the gym more than once per week! Your professor will explain how to track this in class.

If You Miss a Gym Session:

If you cannot attend the gym for any reason, notify your professor immediately. You must provide proper documentation (e.g., doctor's note, accommodation letter) to support your absence.

5. Provide Progress Presentation

Around week five of your project, you will assess your progress and reflect on your experience so far. As part of this, you will give a brief 1- to 2-minute presentation to the class about:

- Your progress so far
- Your experience with the project

This presentation is a practice only for your final presentation, and you are not graded on the quality of your speaking, slides, or results. You simply need to participate in some way — say something, anything — and you will earn full marks for this portion. If you don't participate, you won't receive the marks.

6. Complete Final InBody Assessment and Presentation

At the end of the 8-week project period, you will:

- Complete another InBody Assessment and compare your final results to your starting values
- Prepare a short PowerPoint presentation summarizing your project, including:
 - Your original goals

- The progress you made
- Challenges or setbacks you faced
- Your final results and takeaways

This presentation may be done in front of your classmates or privately with your professor — details will be provided closer to the date.

Important: You must also upload your final InBody Assessment to FOL before the deadline to receive full marks.

Need Additional Help?

Phone: 519.452.4477 ex 14803

Email: wellness@fanshawec.ca

Hours of Operation

Mon-Fri: 7:00 a.m. to 9:00 p.m.

Sat/Sun: 11:00 a.m. to 7:00 p.m.



CHAPTER 1: THE STUDY OF HUMAN MOVEMENT

Chapter Overview

- 1.0 Learning Objectives
- 1.1 Kinesiology
- 1.2 Possible Career Paths
- 1.3 Movement Related Terms
- 1.4 Physical Inactivity & Obesity
- 1.5 Barriers to Physical Activity
- 1.6 Chapter Summary
- 1.7 Knowledge Check

1.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Define kinesiology and list physiological, psychological, and sociological components influencing human movement.
- Summarize the main areas of kinesiology and other names that it may go by.
- List potential career opportunities for kinesiology graduates, including roles within health and fitness as well as careers utilizing transferable skills outside the field.
- Explain similarities and differences between movement, physical activity, physical exercise, and physical fitness, providing relevant examples of each.
- Define and explain the health risks and causes of physical inactivity and obesity on a global scale.
- Identify and categorize barriers to physical activity with appropriate examples.

1.1 KINESIOLOGY

The word **Kinesiology** comes from:

- Kine = Movement
- -ology = The study of

It refers to the systematic, scientific study of human movement, focusing on physiological (i.e. how the body works), psychological (i.e. how the mind affects movement), and sociological (i.e. how society and culture influence activity) factors that influence how and why we move. It also explores how movement can be optimized to improve health, performance, and quality of life.

In other words, kinesiology is about understanding the body in motion and using that knowledge to help people move better, whether for daily life, sports, work, or recovery from injury.

Kinesiology is a broad discipline often divided into four key areas:

1. Exercise Physiology & Anatomy

How the body's systems (muscles, bones, heart, lungs, etc.) respond to and adapt during physical activity. Understanding body function (i.e., what it does) and structure (i.e., what it consists of) helps improve fitness, prevent disease, and maximize physical performance.

Examples:

- How your heart rate changes during exercise
- What your muscles look like during rest and exercise
- How muscles grow (hypertrophy) with strength training
- How oxygen is delivered to your muscles during a run



“Sportswoman checking fitness tracker” by Ketut Sabiyanto, Pexels License

2. Biomechanics, Motor Learning, & Skill Acquisition

Biomechanics applies physics to the human body to better understand movement, forces, and mechanics. Motor learning and skill acquisition focus on how people learn, refine, and master movement skills. This area is vital for athletes, injury prevention, rehabilitation, and improving everyday movement.

Examples:

- Improving a golf swing or jump shot
- Reducing injury risk through better technique
- Analyzing how forces act on joints during exercise



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3. Social, Psychological, & Historical Aspects of Sport

This area helps us understand how sport and movement connect to bigger societal issues, such as history and mental health.

Examples:

- The role of sport in building community
- Gender equity and inclusion in sports
- How mental health impacts physical performance
- The history of physical activity across cultures



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4. Fitness Training, Recreation, & Leisure

Movement isn't just for athletes. It's essential for everyone, from kids to seniors, for health, enjoyment, and quality of life. This area focuses on staying active through everyday life, recreation, and personal fitness.

Examples:

- Designing personal training programs
- Promoting physical activity for older adults
- Encouraging active lifestyles through parks, programs, or workplace initiatives



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Depending on where you study or work, Kinesiology may also be called:

- Exercise Science
- Human Kinetics
- Physical Education
- Sport Science

Although terms such as these are often used interchangeably, they each have slightly different areas of focus. See the table below:

Term	What It Means	Common Focus Areas	Where You'll See It
Kinesiology	A broad study of human movement, health, and performance	Movement Science, fitness, rehab, sport, health promotion	Universities, health fields, and fitness industries
Exercise Science	Scientific study of exercise and how it affects the body	Exercise testing, training programs, health outcomes, and performance	Research labs, sports teams, and personal training
Human Kinetics	Another term for Kinesiology, often with more emphasis on health	Physical activity, health, wellness, rehabilitation	Canadian universities, wellness programs
Physical Education	Teaching movement skills and promoting active lifestyles	Education, motor skills, youth development, and health promotion	Schools, community programs, and teacher training
Sport Science	Study of athletic performance, often at a high level	Elite sport, performance analysis, biomechanics, injury prevention	Pro sports, high-performance coaching, and research

Regardless of the title, they all use scientific principles to better understand and improve human movement.

1.2 POSSIBLE CAREER PATHS



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Kinesiology graduates are highly employable. A degree or diploma in Kinesiology or a related discipline can lead to many different careers. Some are directly related to health and fitness, while others may surprise you!

Careers Directly Related to Kinesiology:

- Personal Trainer
- Kinesiologist
- Athletic Therapist
- Researcher
- Physiotherapy or Occupational Therapist
- Fitness Instructor
- Strength and Conditioning Coach
- Recreation Program Coordinator

- Sports Coach
- Ergonomic or Workplace Wellness Specialist
- Health Promotion Specialist

Careers in Related Fields (Often with Additional Training):

- Physical Education Teacher
- Physician
- Chiropractor
- Registered Massage Therapist
- Nurse or Physician
- Exercise Physiologist
- Cardiac Rehabilitation Specialist
- Sports Psychologist

Careers Outside of Kinesiology:

Believe it or not, many Kinesiology graduates work in jobs that aren't directly tied to movement or exercise. That's because Kin programs build transferable skills like communication, problem-solving, leadership, and discipline, skills that employers value in many fields.

- Banking
- Insurance
- Sales and Marketing
- Business Management
- Law Enforcement
- Customer Service
- Human Resources
- Politics



Photo by Christina Morillo, Pexels License

1.3 MOVEMENT RELATED TERMS

Many people use the following terms interchangeably, but they have distinct meanings:

Movement

Refers to any action or change in the position of the body or its parts that is produced by muscle contractions. Movement allows us to interact with our environment, perform daily tasks, and maintain essential life functions.

Some movements, like walking or reaching for an object, are voluntary, while others, such as your heartbeat or reflexively pulling your hand away from something hot, happen without conscious control.

Physical Activity

Any bodily movement created by skeletal muscles that results in energy expenditure beyond what occurs at rest. Physical activity is essential for health and maintaining function, and contributes to how many calories you burn throughout the day.

It can be structured or unstructured and includes simple daily actions like walking to work, gardening, shovelling snow, or playing with your children.

Physical Exercise

A specific type of physical activity that is planned, structured, and repetitive, done with the goal of improving or maintaining physical fitness.

Unlike casual physical activity, exercise is always intentional and targets areas like strength, endurance, flexibility, or balance. Examples include jogging regularly, following a strength-training program, attending yoga classes, swimming laps, or practicing sports.

Physical Fitness

Refers to a set of measurable qualities that relate to how well a person can perform physical activity. These

attributes reflect the body’s ability to function efficiently and effectively in daily life while minimizing health risks.

Fitness improves through consistent physical activity and includes cardiovascular endurance, muscular strength, flexibility, balance, coordination, and maintaining a healthy body composition.

Comparison of Terms

Term	Definition	Purpose	Examples
Movement	Any bodily motion, voluntary or involuntary	Basic life functions, interaction	Reaching, standing, and posture shifts
Physical Activity	Body movement that increases energy use above rest	General health, daily functioning	Walking, climbing stairs, yard work
Physical Exercise	Planned, structured activity to improve fitness	Targeted fitness improvements	Running program, gym workouts, fitness classes
Physical Fitness	The ability to perform tasks efficiently, measured through specific components	Health, resilience, quality of life	Cardiovascular endurance, strength, and flexibility

1.4 PHYSICAL INACTIVITY & OBESITY

Physical inactivity and **obesity** are among the most significant global health challenges. While they are closely linked, they are distinct issues that together contribute to rising rates of chronic disease, disability, and premature death.

Beyond the personal health consequences, these issues place a huge financial burden on health care systems, especially in countries like Canada that have publicly funded health care. In these systems, taxpayers ultimately cover the cost of treating preventable conditions related to inactivity and obesity, such as heart disease, diabetes, certain cancers, and mobility problems.

Physical Inactivity

Physical inactivity refers to a level of activity that is insufficient to meet current physical activity recommendations. The World Health Organization (WHO, n.d.) defines physical inactivity as engaging in less than:



150 minutes of moderate-intensity aerobic activity per week



or **75 minutes** of vigorous-intensity activity per week



or an **equivalent combination** of both

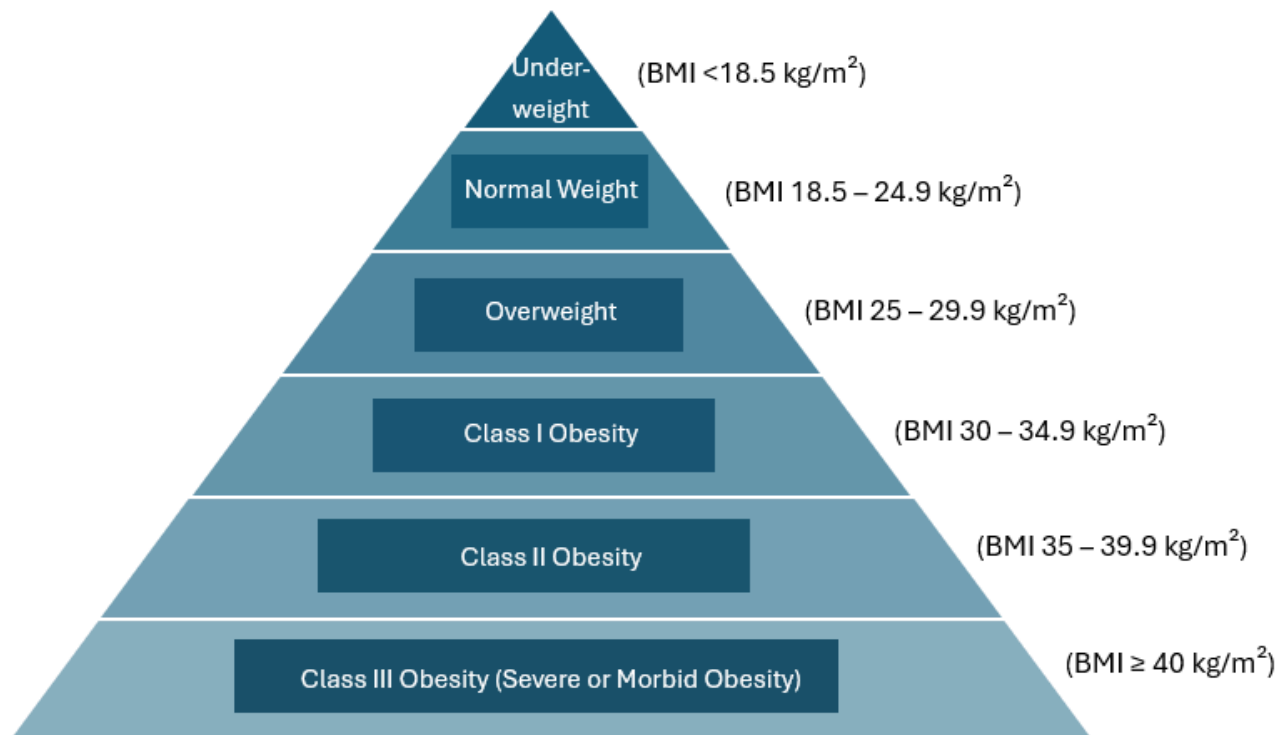
“Dog walking”, “Bike ride” and “Activity tracker” by Undraw, Undraw License Modified: Added text

Key Statistics:

- Globally, 33.8% of women and 28.7% of men are physically inactive (WHO, 2024).
- In the Americas, inactivity rates are even higher, with 40.6% of women and 30.5% of men not meeting guidelines (PAHO, 2024).

Obesity

A medical condition characterized by excess body fat that may impair health. It is commonly measured using BMI:



“BMI Triangle” by saudette, CC BY-NC-SA 4.0

Image Description

The diagram is a pyramid chart illustrating Body Mass Index (BMI) categories, arranged from the lowest to the highest BMI values. The pyramid is divided into seven horizontal sections, with each section representing a different BMI classification. From top to bottom, the sections are:

1. Underweight – BMI less than 18.5 kg/m^2 (smallest section at the top)
2. Normal Weight – BMI between 18.5 and 24.9 kg/m^2
3. Overweight – BMI between 25 and 29.9 kg/m^2
4. Class I Obesity – BMI between 30 and 34.9 kg/m^2
5. Class II Obesity – BMI between 35 and 39.9 kg/m^2
6. Class III Obesity (Severe or Morbid Obesity) – BMI 40 kg/m^2 or higher (widest section at the bottom)

Key Statistics:

- According to the Financial Times (O'Hare, 2024), adult obesity has more than doubled since 1990:
 - Men: from 4.8% to 14.0%
 - Women: from 8.8% to 18.5%
- Over 1 billion people worldwide are now living with obesity (The Sun, 2024)

What is your Body Mass Index (BMI)?

You can calculate your own **BMI** by using this online BMI Calculator provided by Diabetes Canada. (Note: BMI is a quick screening tool but does not directly measure body fat percentage or distinguish between muscle and fat mass.)

Physical Inactivity vs. Obesity

Aspect	Physical Inactivity	Obesity
Definition	Not meeting recommended activity levels	Excess body fat that impairs health (BMI ≥ 30 kg/m²)
Cause or Outcome?	Often, a contributing factor to obesity	It can be a result of inactivity, but it can also be influenced by diet, genetics, etc.
Health Risks	Increased risk of heart disease, diabetes, and poor mental health	Increased risk of heart disease, diabetes, cancer, and mobility issues
Modifiable?	Yes, through increased activity	Yes, through physical activity, diet, and medical interventions
Independent Risks?	Yes, even active people can experience health risks if sedentary for long periods.	Yes, obesity increases health risks regardless of activity level.

Causes of Physical Inactivity and Obesity

Shared Causes:

- Sedentary lifestyles (desk jobs, screen time)
- Urban environments limit active transportation
- Reduced access to recreational spaces
- Increased reliance on cars
- Poor health literacy

Obesity-Specific Causes:

- Excess calorie consumption
- Poor diet (high in processed foods, sugars)
- Metabolic or genetic predispositions
- Hormonal factors
- Psychological factors (stress, emotional eating)

1.5 BARRIERS TO PHYSICAL ACTIVITY

In this context, a **barrier** refers to anything that prevents or makes it more difficult for a person to engage in regular physical activity. Barriers can be external (environmental, cultural) or internal (personal, psychological) and often interact to influence behaviour.



Barriers to Physical Activity

Click on each icon to learn more about the types of barriers that can prevent physical activity.

Text Description

Environmental Barriers

- External, physical factors in a person's surroundings make it harder to engage in activity. These barriers limit access to safe, convenient, or appealing spaces for movement.
- Lack of safe walking paths, parks, or recreational spaces
- Unsafe neighbourhoods or high crime rates
- Poor urban design (e.g., car-dependent communities)
- Seasonal challenges like extreme heat, cold, or snow
- Limited access to gyms or facilities, especially in rural areas

Socioeconomic Barriers

- Obstacles related to a person's financial situation, work demands, or access to resources that affect their ability to be physically active.
- Cost of gym memberships, equipment, or sports programs
- Limited access to transportation

- Working multiple jobs or long hours
- Lack of affordable childcare
- Financial insecurity leads to prioritizing basic needs over exercise

Personal Barriers

- Individual-level challenges that stem from a person's mindset, physical condition, knowledge, or motivation discourage participation in the activity.
- Low motivation or lack of enjoyment
- Poor self-confidence or fear of failure
- Body image concerns
- Physical limitations or chronic pain
- Lack of knowledge about how to exercise safely

Fatigue or low energy, especially in populations with demanding schedules or health conditions

- Cultural and Social Barriers
- Beliefs, customs, social norms, or expectations within a person's community or culture that discourage or limit physical activity.
- Gender norms or expectations restricting participation
- Cultural beliefs that discourage certain types of activity
- Lack of family or social support
- Language barriers in accessing programs
- Religious practices influencing activity choices or clothing restrictions

Psychological and Emotional Barriers

- Mental health challenges, emotional states, or cognitive patterns that reduce motivation, increase avoidance, or make activity seem overwhelming.
- Depression, anxiety, or other mental health challenges reduce motivation
- Stress, leading people to prioritize other tasks over the activity
- Fear of injury or exacerbating a health condition

Summary of Terms

Type of Barrier	Definition	Examples
Environmental	Physical surroundings that limit safe, accessible, or appealing activity	Lack of parks, unsafe streets, harsh weather, and no sidewalks
Socioeconomic	Financial or resource-related challenges affecting participation	High cost of gyms, no transportation, and long work hours
Personal	Individual challenges related to mindset, ability, or knowledge	Low confidence, lack of energy, physical limitations, and inexperience
Cultural and Social	Beliefs, norms, or social influences that discourage activity	Gender expectations, religious restrictions, and lack of support
Psychological and Emotional	Mental health or emotional factors that reduce motivation or increase avoidance	Depression, anxiety, fear of failure, stress, and fear of injury

1.6 CHAPTER SUMMARY

Key Takeaways

- Kinesiology is the study of how the body, mind, and society influence how and why we move.
- Graduates from kinesiology-related post-secondary programs go on to pursue a variety of career paths, some kin-related, some not.
- Movement, physical activity, physical exercise, and physical fitness are related but have distinct meanings.
- Physical inactivity and obesity are prevalent and costly health challenges worldwide.
- Barriers to being physically active can be environmental, financial, personal, cultural, and/or mental health-related.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into key takeaways.

 Key Terms

- **Biomechanics:** The application of physics to human movement to understand forces, motion, and mechanics of the body.
- **Body Mass Index (BMI):** A screening tool that uses a person's height and weight to classify weight categories (e.g., overweight, obese).
- **Barrier:** Any factor that prevents or discourages regular physical activity, either internal (personal) or external (environmental/social).
- **Cultural and Social Barriers:** Social or cultural norms, beliefs, or expectations that discourage participation in physical activity.
- **Environmental Barriers:** Physical surroundings that make it difficult to be active, such as unsafe neighbourhoods or a lack of facilities.
- **Exercise Physiology & Anatomy:** The study of how the body's systems (muscles, bones, heart, lungs) respond and adapt to physical activity.
- **Fitness Training, Recreation & Leisure:** A focus on promoting movement and physical activity across all age groups for enjoyment and wellbeing.
- **Kinesiology:** The scientific study of human movement, focusing on how the body, mind, and society influence movement to improve health, performance, and quality of life.
- **Motor Learning & Skill Acquisition:** The processes by which people learn and improve movement skills over time.
- **Movement:** Any action of the body or body parts caused by muscle contraction, including voluntary and involuntary actions.
- **Obesity:** A medical condition characterized by excess body fat that can impair health; commonly measured using BMI.
- **Personal Barriers:** Individual factors like low motivation, poor self-confidence, physical limitations, or lack of knowledge.
- **Physical Activity:** Any body movement produced by skeletal muscles that requires energy expenditure beyond resting levels.

- **Physical Exercise:** A structured, planned, and repetitive form of physical activity intended to improve physical fitness.
 - **Physical Fitness:** A set of measurable characteristics (e.g., endurance, strength, flexibility) related to the body's ability to perform physical activity efficiently.
 - **Physical Inactivity:** Engaging in less than the recommended levels of physical activity (e.g., fewer than 150 minutes of moderate activity per week).
 - **Psychological and Emotional Barriers:** Mental and emotional factors like stress, depression, anxiety, or fear that reduce motivation to be active.
 - **Social, Psychological & Historical Aspects of Sport:** The study of how movement and sport relate to societal issues, mental health, and cultural history.
 - **Socioeconomic Barriers:** Financial or resource-related challenges, such as the cost of gyms, lack of transportation, or work demands.
-

OpenAI. (July 8th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>.
Prompt: List the key terms and their definitions in the content provided.

1.7 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. What is the primary focus of kinesiology?

- Measuring body fat percentage
- The scientific study of human movement
- Creating meal plans for athletes
- Teaching anatomy and physiology

2. Which of the following best defines physical activity?

- Any movement, intentional or not
- Bodily movement produced by skeletal muscles that requires energy expenditure
- Planned and structured body movement
- The ability to perform physical tasks efficiently

3. Which of the following terms refers to a structured and repetitive activity aimed at improving fitness?

- Movement
- Physical exercise
- Physical activity
- Physical fitness

4. Which of the following is NOT an example of an environmental barrier to physical activity?

- Lack of sidewalks
- Unsafe neighbourhoods
- Low motivation
- Extreme weather

5. Which term is often used interchangeably with Kinesiology but emphasizes health and rehabilitation?

- Sport Science
- Physical Education
- Human Kinetics
- Exercise Science

6. What is the World Health Organization's recommendation for minimum moderate-intensity activity per week?

- 60 minutes
- 100 minutes
- 150 minute
- 200 minutes

7. What does Body Mass Index (BMI) primarily measure?

- Body composition
- Muscle-to-fat ratio
- Weight relative to height
- Resting heart rate

Correct Answers:

1. The scientific study of human movement
2. Bodily movement produced by skeletal muscles that requires energy expenditure
3. Physical exercise

4. Low motivation
5. Human Kinetics
6. 150 minutes
7. Weight relative to height

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 2: FITT PRINCIPLE

Chapter Overview

- 2.0 Learning Objectives
- 2.1 What is the FITT Principle?
- 2.2 Beginner Example
- 2.3 Intermediate Example
- 2.4 Advanced Example
- 2.5 Chapter Summary
- 2.6 Knowledge Check

2.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Define the FITT Principle and explain what each variable (Frequency, Intensity, Time, Type) stands for.
- Identify appropriate ways to measure and track workout intensity.
- Distinguish how the FITT Principle should be applied differently for beginner, intermediate, and advanced fitness levels.
- Describe how FITT variables can be adapted to suit various fitness goals, such as weight loss, strength development, or athletic performance.
- Explain the importance of tailoring FITT variables to match individual needs, experience level, and recovery capacity.
- Apply the FITT Principle by designing or assessing exercise plans for individuals with different fitness levels and goals.

2.1 WHAT IS THE FITT PRINCIPLE?

The **FITT Principle** provides a simple and structured approach to building effective, safe, and goal-oriented exercise programs. Each variable within FITT plays a specific role in shaping weekly workouts and outcomes:



F = Frequency

How often do you perform a physical activity/exercise?



I = Intensity

How hard are you working during the physical activity/exercise?



T = Type

What specific exercise did you choose to perform?



T = Time

How long do you spend performing the exercise/activity?

F = Frequency

This is typically measured by how many sessions you complete each week. Ideal frequency depends on your fitness level, personal goals, and the type of exercise you are doing.

General guidelines recommend aerobic activity three to five days per week, strength training two to three non-consecutive days per week, and flexibility exercises like stretching at least three times per week.

Tracking how often you train is useful, but it's equally important to monitor rest days to ensure proper recovery and reduce the risk of injury. For those just starting out, aiming for two to four sessions per week provides time for recovery, helps build consistency, and reduces the chance of burnout or excessive soreness. More advanced individuals may train five to six days per week, often using split routines or alternating training goals (e.g., strength one day and aerobic conditioning the next) to optimize results while managing fatigue.

I = Intensity

Generally, the harder you work, the greater the potential improvements, but also the higher the demand on your body. Understanding intensity and knowing how to adjust it helps ensure your workouts are effective, sustainable, aligned with your goals, and performed safely.

Intensity can be measured in a variety of ways:

Percentage of Maximum Heart Rate (MHR)

One of the most common ways to measure intensity during aerobic activities is by monitoring your heart rate. To estimate your maximum heart rate, subtract your age from 220. Then, multiply your maximum heart rate by the percentage you wish to achieve.

Intensity Level	% of HRmax	Goal
Light Activity	50–60%	Warm-up; easy activity; recovery
Moderate Intensity	60–70%	Fat burning, general health, aerobic base
Vigorous Intensity	70–85%	Improving endurance and fitness
Maximal Effort	85–100%	Sprinting; high-intensity

For example, if you are 20 years old, your estimated max heart rate would be 200 beats per minute. Moderate intensity exercise would range between 120 and 140 beats per minute.

Percentage of 1 Repetition Maximum (1RM)

In resistance training, intensity is often measured by the percentage of your one-repetition maximum (1RM): the maximum amount of weight you can lift once with proper form.

Higher percentages of your 1RM indicate greater intensity and are typically used to develop strength or power.

Reps Performed	% of 1RM (Estimated)	Intensity Level
1	100%	Maximal
2	95%	Very High
3	93%	Very High
4	90%	High
5	87%	High
6	85%	Moderate-High
7	83%	Moderate-High
8	80%	Moderate
9	77%	Moderate
10	75%	Moderate

How to Estimate 1RM from a Submaximal Lift

Attempting a true 1RM is not recommended for beginners due to the higher risk of injury. Instead, you can perform a submaximal test, such as an 8-repetition maximum, and then estimate your 1RM using the Epley Formula:

$$\text{Estimated 1RM} = \text{Weight lifted} \times (1 + \text{reps} \div 30)$$

Example: You bench press 80 kg for six reps:

$$1RM = 80 \times (1 + 6 \div 30)$$

$$1RM = 96\text{kg (approx)}$$

Note: This formula is most accurate for sets of 10 reps or fewer. For anything beyond 10 to 12 reps, the accuracy decreases.

Rate of Perceived Exertion (RPE)

The RPE scale is a subjective tool that helps gauge exercise intensity based on how hard you feel you are working. This scale typically ranges from 1 to 10, where 1 represents very light intensity and 10 represents maximal intensity or effort.

RPE	Intensity Level	Description
0	Rest	No effort; completely at rest
1	Very Light	Easy breathing; barely any effort
2	Light	Can hold a conversation easily
3	Moderate	Comfortable pace; can talk but not sing
4	Somewhat Hard	Breathing heavier, can talk in short sentences
5	Hard	Challenging but sustainable for a while
6	Hard+	Becoming difficult to maintain; heart rate elevated
7	Very Hard	Struggling to talk; effort feels tough
8	Extremely Hard	Near maximal; cannot sustain for long
9	Very, Very Hard	Almost all-out; gasping for air
10	Max Effort	All-out sprint or lift; only sustainable for a few seconds

For example, running at a pace where you can still talk but not sing would likely be moderate intensity (3), while struggling to say more than a few words suggests higher intensity (5 to 7).

For beginners, intensity should stay low to moderate (RPE 3 to 6). The goal is to prioritize good form, build confidence, and reduce injury risk. Advanced exercisers require higher intensity (RPE 7 to 9) to continue making gains, as their bodies are more efficient and resilient.

T = Type

While exercise is often discussed in broad categories (e.g., cardio, strength, or flexibility), the actual type should refer to the specific activity or exercise you are doing within those categories. Simply saying “I do cardio” is far too general. The more specific you are when selecting your exercise type, the more effectively you can tailor your routine to meet your needs.

Possible Cardiovascular or Aerobic Types	Possible Strength Training Types	Possible Flexibility Training Types
• Walking (indoors or outdoors) • Jogging or running • Biking • Hiking • Dancing • Rowing • Shadowboxing • Stair climbing • Elliptical trainer • Burpee • Mountain Climber	• Shoulder Press • Chest Press • Bent-Over Row • Bicep Curl • Triceps Kickback • Push-up • Pull-up • Squat • Deadlift • Good morning • Lunge • Step-up • Weighted sit-up • Plank	• Neck Stretch • Shoulder Stretch • Triceps Stretch • Chest Opener • Seated Hamstring Stretch • Standing Quad Stretch • Hip Flexor Stretch • Figure 4 Glute Stretch • Calf Stretch • Spinal Twist

Your exercise type should match your goal. Want better endurance? Choose running, biking, or swimming. Want to build muscle? Use weights or bodyweight exercises like squats and push-ups.

Beginners should focus on simple, low-risk and accessible exercises like walking, bodyweight movements, and resistance bands. Individuals with experience and/or advanced fitness levels may choose to incorporate complex lifts (e.g., power cleans), plyometrics, sprints, and heavy compound movements that require greater coordination, strength, and training experience.

T = Time

For cardiovascular exercise, flexibility work, or other continuous movements, time is often measured in seconds or minutes. For resistance training and other related exercises, using seconds or minutes is not ideal. Instead, sets and repetitions (reps) are used to measure the total volume of resistance training, since simply counting minutes doesn't accurately reflect how much work you've done.

For example, rather than saying you "did push-ups for 10 minutes," it's more meaningful to say you completed three sets of 10 reps of push-ups, because this provides clear information about the amount of work performed. That's how volume and progression are tracked effectively in strength programs.

In some cases, especially with static exercises like planks, wall sits, or isometric holds, a combination of sets, reps, and time is used. For example, performing three sets of a 45-second plank hold is a common approach that blends both time and sets to track progress.

Possible Isometric (Hold-Based) Exercises	Possible Timed Cardio or Conditioning Drills
• Plank (front or side) • Wall sit • Glute bridge hold • Hollow body hold • Superman hold • V-sit hold • Isometric lunge hold • Dead hang (from bar)	• Jumping jacks • High knees • Mountain climbers • Burpees • Skater jumps • Jump rope • Butt kicks • Speed punches • Fast feet • Shadowboxing

Beginners often benefit from shorter exercise durations and longer rest periods to allow for proper technique, recovery, and habit formation. Advanced individuals can typically handle longer sessions and higher training volumes not just because of their improved fitness, but because their bodies are more efficient at recovering and sustaining effort.

Summary of Terms

Term	What it Means	How We Measure It	Examples
Frequency	How often do you perform a physical activity/exercise?	Number of instances per week	Run 3 times per week, run 5 times per week, run 10 times per week
Intensity	How hard are you working during the physical activity/exercise?	– % of max HR, RPE, 1RM	Run at 70% of max HR; Run at RPE of 6/10; Bench press at 75% of 1RM
Type	What specific exercise did you choose to perform?	Not measured per se. It is chosen based on your fitness goals	Running, push-ups, plank, and quadricep stretch
Time	How long do you spend performing the exercise/activity?	Minutes/seconds per session or set	Walk for 30 minutes; 8 sets of 4 repetitions bench press; 2 sets of 45-second plank

Applying the FITT Principle

The FITT Principle is highly adaptable. There’s no single “right” way to structure a program. Different combinations of frequency, intensity, time, and type can all be effective and appropriate depending on a person’s goals, preferences, fitness level, and lifestyle.

That said, some approaches are more appropriate than others, especially when considering safety, experience level, and long-term success. A beginner needs a very different plan from a trained athlete. The key is to meet people where they’re at, using FITT to create realistic, effective, and personalized programs that help them build confidence, consistency, and results.

To show how FITT can be tailored to different individuals, let’s walk through three distinct examples – Alex, Jasmine, and Rohan.

2.2 BEGINNER EXAMPLE

Beginner Example: Alex

Alex is a 19-year-old first-year college student. He spends a lot of time sitting in lectures, studying, or gaming. He recently realized he's feeling sluggish, gaining weight, and struggling with energy and focus. He wants to feel healthier, manage stress, and get into better shape, but he's unsure where to start and doesn't feel comfortable in a gym just yet.

Possible FITT for Alex:

Frequency (F)	Intensity (I)	Type (T)	Time (T)
3 times per week	60% MHR	Walking	20 minutes
2 times per week	75% 1RM	Bench Press	3 sets of 12 reps
2 times per week	RPE: 6	Dumbbell Row	4 sets of 8 reps
2 times per week	RPE: 6	Goblet Squat	3 sets of 15 reps
3 times per week	RPE: 7	Plank	3 sets of 30 seconds

Why This FITT?

To help Alex ease into fitness, simple, accessible exercises have been selected that can be done at home or in a basic fitness facility. Frequency is kept moderate to help build consistency and habit without feeling overwhelmed. Training occurs every other day of the week, but with lower overall volume. Intensity and times are light to moderate to prioritize form, reduce injury risk, and improve confidence.

2.3 INTERMEDIATE EXAMPLE



Intermediate Example: Jasmine

Jasmine is a 29-year-old elementary school teacher who's been consistently working out for over a year. She enjoys strength training and wants to increase muscle tone, especially in her legs and arms. She also wants to keep her heart healthy with occasional cardio and is comfortable using free weights and gym equipment.

Possible FITT for Jasmine:

Frequency (F)	Intensity (I)	Type (T)	Time (T)
4 times per week	70-85% MHR	Stationary Bike Intervals	20 minutes (1 minute fast, 1 minute rest)
3 times per week	80% 1RM	Barbell Deadlift	5 sets of 8 reps
2 times per week	RPE: 6	Dumbbell walking lunge	3 sets of 12 reps per leg
3 times per week	RPE: 7	Seated Cable Row	3 sets of 10 reps
3 times per week	RPE: 6	Dumbbell Bicep Curls	2 sets of 15 reps

Why This FITT?

This plan includes a mix of full-body and targeted exercises. This means some exercises work several muscles at once (like squats), while others focus on specific areas she wants to tone, like her arms and legs. Cardio is added in short bursts to help her heart and lungs without needing long workouts. She will exercise a few times each week, which matches her good habits and ability to recover. The workouts are a bit harder

than at the beginner level, so she uses medium weights and effort (RPE around 6 or 7) to help her get stronger while keeping the workouts safe and manageable.

2.4 ADVANCED EXAMPLE

Advanced Example: Rohan

Rohan is a 35-year-old recreational rugby player training in the off-season to boost strength, speed, and explosiveness. He has years of lifting experience and includes Olympic lifts, sprints, and heavy compound movements in his weekly routine.

Possible FITT for Rohan:

Frequency (F)	Intensity (I)	Type (T)	Time (T)
2 times per week	85 to 90% 1RM	Power Clean	5 sets of 3 reps
3 times per week	RPE: 8	Weighted Pull-ups	4 sets of 5 reps
2 times per week	RPE: 8	Box Jumps	3 sets of 7 reps
3 times per week	RPE: 7	Wall Sit	3 sets of 90 seconds
5 times per week	70% MHR	Running	25 minutes

Why this FITT?

Rohan's workout plan is built to help him get better at rugby by improving his strength, speed, and power. Exercises like power cleans, box jumps, and weighted pull-ups help him build muscles that are strong and fast, important for tackling, sprinting, and staying powerful during a game. Sprints and wall sits help him build endurance, body control, and mental toughness. His training is split up so he can lift heavy weights without getting too tired, while still doing lots of running and fitness work to stay in shape for

games. The workouts are tough, using heavy weights and hard effort (about 8 out of 10 or more), to push his body to the next level and help him perform better on the field.

2.5 CHAPTER SUMMARY

Key Takeaways

- FITT stands for Frequency, Intensity, Time, and Type.
- The FITT Principle is a foundational tool used to create structured, personalized, and goal-oriented fitness programs.
- Each FITT variable helps specify how often, how hard, how long, and what type of exercise someone should do based on their goals and current fitness level.
- There is no single correct approach to FITT, but some combinations are more appropriate than others depending on experience, safety, and recovery needs.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into key takeaways.

 Key Terms

- **Cardiovascular Exercise:** Activities that raise heart rate and improve heart/lung endurance (e.g., biking, swimming, jogging).
- **Epley Formula:** A method to estimate 1RM from a submaximal effort: $1RM = \text{weight} \times (1 + \text{reps} \div 30)$
- **Flexibility Training:** Exercises aimed at increasing joint range of motion and muscle length (e.g., hamstring stretch, spinal twist).
- **FITT Principle:** A guideline used to design effective exercise programs by adjusting four key variables: Frequency, Intensity, Time, and Type.
- **Flexibility Training:** Exercises aimed at increasing joint range of motion and muscle length (e.g., hamstring stretch, spinal twist).
- **Frequency:** How often you perform an exercise or activity, typically measured in sessions per week.
- **Intensity:** How hard you are working during exercise. It can be measured using % of Max Heart Rate (MHR), % of One Repetition Maximum (1RM) for strength training, and Rate of Perceived Exertion (RPE).
- **Isometric Exercises:** Exercises involving muscle contraction without movement (e.g., planks, wall sits).
- **One Repetition Maximum (1RM):** The maximum amount of weight a person can lift for one complete repetition with proper form.
- **Rate of Perceived Exertion (RPE):** A scale from 0 to 10 used to subjectively rate how difficult an exercise feels. (1 = very light effort, 10 = maximal effort)
- **Resistance Training:** Exercises that use weights or body weight to build muscle strength (e.g., push-ups, squats, deadlifts).
- **Time:** How long the activity lasts, measured in minutes/seconds for cardio and flexibility, or in sets and repetitions for resistance training.
- **Type:** The specific kind of exercise you choose (e.g., running, squats, yoga), based on your fitness goals like endurance, strength, or flexibility.

OpenAI. (July 22nd, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Create a simple list of key terms and their definitions in the content provided.

2.6 KNOWLEDGE CHECK

Knowledge Check

Text Description:

1. **What does the “F” in the FITT Principle stand for?**
 - Fitness
 - Flexibility
 - Frequency
 - Function
2. **Which of the following best describes “Intensity” in a workout?**
 - How long your workout lasts
 - How often you work out
 - The type of exercise you do
 - How hard you are working during the workout
3. **What is the recommended formula to estimate your 1RM (One Repetition Maximum)?**
 - $\text{Weight lifted} \div \text{number of reps}$
 - $\text{Weight lifted} \times \text{number of reps}$
 - $\text{Weight lifted} \times (1 + \text{reps} \div 30)$
 - $\text{Weight lifted} + 10\%$

4. **If your RPE (Rate of Perceived Exertion) is 3, how would you describe the intensity?**

- Maximal effort
- Moderate pace
- Very hard effort
- Resting state

5. **Which of the following is NOT an example of a flexibility exercise?**

- Hamstring stretch
- Plank
- Chest opener
- Seated quad stretch

6. **A beginner following the FITT Principle should:**

- Train 6–7 times a week at high intensity
- Focus on short, low-to-moderate intensity workouts
- Use Olympic lifts and advanced techniques
- Skip rest days to build consistency

7. **Which method is NOT used to measure exercise intensity?**

- Percentage of Max Heart Rate
- Number of days per week
- Rate of Perceived Exertion (RPE)
- Percentage of 1 Repetition Maximum

Correct Answers:

1. Frequency
2. How hard you are working during the workout

3. $\text{Weight lifted} \times (1 + \text{reps} \div 30)$
4. Moderate pace
5. Plank
6. Focus on short, low-to-moderate intensity workouts
7. Number of days per week

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 3: DIRECTIONAL AND MOVEMENT TERMS

Chapter Overview

- 3.0 Learning Objectives
- 3.1 Anatomical Language
- 3.2 Anatomical Position
- 3.3 Dividing The Body
- 3.4 Directional Terms
- 3.5 Movement Terms
- 3.6 Chapter Summary
- 3.7 Knowledge Check

3.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Identify and define common anatomical prefixes and suffixes, and explain how they help break down complex terms.
- Describe anatomical position and explain its importance as a universal reference point in kinesiology.
- Differentiate between the three anatomical planes and axes and match them with appropriate movement examples.
- Use directional terms (e.g., anterior, superior, distal) to describe the location of body parts in relation to one another.
- Define and provide examples of common joint movements (e.g., flexion, abduction) and identify which plane and axis each movement occurs in.
- Communicate and interpret exercise instructions or movement cues using correct anatomical and directional terminology.

3.1 ANATOMICAL LANGUAGE

Learning movement and fitness-related terms is like learning a new language. Many of these words are built from parts (prefixes and suffixes) that act like “building blocks.” Once you understand what these parts mean, it becomes much easier to break down complicated terms and understand instructions, diagrams, or exercises without memorizing every single word.

For this course, knowing these parts will help you:

- Understand body positioning (e.g., anterior = front)
- Follow movement instructions (e.g., abduction = away from the midline)
- Communicate more clearly about exercises and movement

It’s like cracking a code. Once you know the parts, the whole term makes so much more sense!

Prefix/Suffix	Meaning
Ab-	Away from
Ad-	Toward
Post-	After, behind
Super- / Supra-	Above, over
Infra-	Below, beneath
Inter-	Between
Intra-	Within
Sub-	Under, below
Epi-	On, upon, above
Circum-	Around
Trans-	Across, through
Hyper-	Over, excessive
Hypo-	Under, below normal
Dorsi-	Back, upper
Plantar-	Sole of the foot
-flexion	Bending or decreasing the angle
-extension	Straightening or increasing the angle
-duction	Movement
-version	Turning
-logy	Study of



Try This!

Let's practise cracking the code. Read each word and guess its meaning based on the bolded suffix/prefix. Flip each card to check your answer.

Text Description

This activity contains a set of dialogue cards, which are described below.

Front of card:

1. **Ep**icondyle
2. **Inter**vertebral
3. In**ver**sion, E**ver**sion
4. **Sub**cutaneous
5. **Trans**verse Plane
6. **Circum**duction
7. **Post**erior
8. **Ext**ension
9. **Ab**duction
10. **Intra**muscular
11. **Hypo**tension
12. **Add**uction
13. **Infrac**spinatus
14. **Dors**iflexion
15. **Hyper**extension
16. **Flex**ion
17. **Plantar**flexion
18. **Superior**, **Supra**spinatus
19. Kinesi**ology**

Back of card:

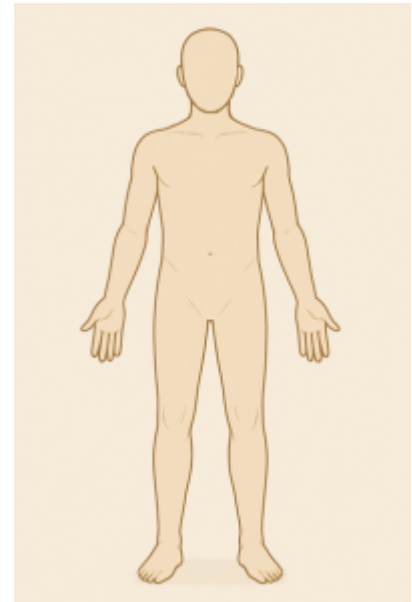
1. A structure sitting **on or near** a condyle
2. Located **between** vertebrae
3. Turning the sole of the foot **inward** or **outward**
4. **Under** the skin
5. A plane cutting **across** the body horizontally
6. Movement in a **circular** pattern
7. **Back side** of the body
8. **Straightening** or **increasing** the angle
9. Moving **away from** the body's midline
10. **Within** the muscle
11. Abnormally **low** blood pressure
12. Movement **toward** the body's midline
13. Located **below** a reference structure
14. Flexing the foot **upward** toward the shin
15. Movement **beyond** the normal extension range
16. **Bending** or **decreasing** the angle
17. Pointing the **sole of the foot** downward
18. Located **above** another structure
19. The **study of** movement

3.2 ANATOMICAL POSITION

Anatomical position is the standard, agreed-upon starting point used to describe the human body's structure, movement, and location of body parts.

How to Perform Anatomical Position

- Stand upright, tall, and facing forward
- Feet flat on the floor, shoulder-width apart
- Arms relaxed at your sides
- Palms facing forward
- Fingers extended, thumbs pointing away from the body
- Head and eyes facing straight ahead



Why Use Anatomical Position?

Anatomical position creates consistency so that everyone (e.g., students, health professionals, trainers, researchers, etc.) is speaking the same language when describing parts of the body relative to one another. Without this universal frame of reference, descriptions like “left,” “right,” “in front of,” or “behind” could be confusing. This is especially true if someone is lying down, facing away, or moving around.

“Anatomical Position” See source below

Imagine giving someone directions: You always assume north is “up” on the map, even if you’re facing a different direction. Anatomical position works the same way! No matter how someone is standing, lying, or moving, descriptions like “anterior” or “posterior” always refer to the body in this position.

“Anatomical Position” Image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Create a generic simplified image of the human body that is a faceless mannequin and represents a neutral anatomical model.

3.3 DIVIDING THE BODY

Sometimes, terms are used to help us describe and analyze how the body moves in space. Similar to how anatomical position gives a universal system for describing location, they provide a universal system for interpreting, describing and understanding movement.

Planes

Planes are flat, imaginary surfaces that slice the body into sections. All movements, whether they be at a specific joint or the whole body, happen along one of these planes.

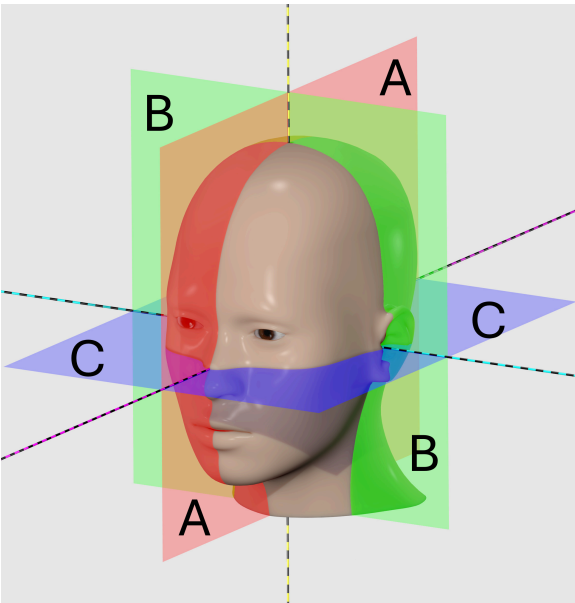


Image by Slashme, CC BY-SA 4.0
Modifications: text added

Plane	Description	Example Movement
A. Sagittal (red)	Divides the body into left and right halves	Walking forward; elbow bending; squats; somersault
B. Frontal (green)	Divides the body into front and back halves	Side shuffle, Jumping jacks, lateral shoulder raises
C. Transverse (purple)	Divides the body into top and bottom halves	Rotational movements, twisting, spinning

Axes

Axes are imaginary lines that run through the body, around which movement occurs. Think of an axis like the pin in a door hinge; the door moves around that axis.

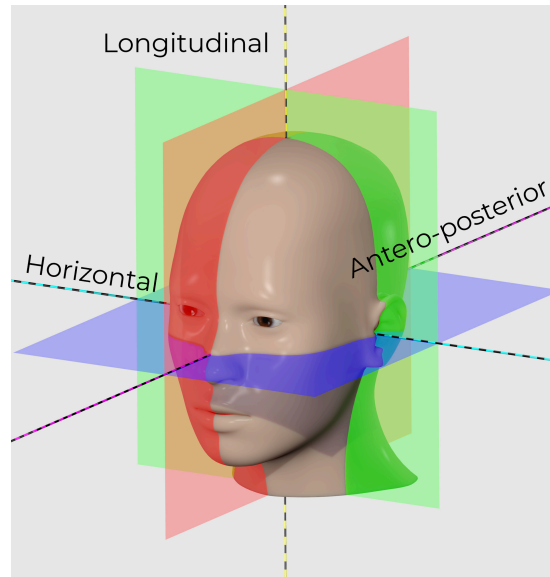


Image by Slashme, CC BY-SA 4.0 Modifications:
text added

Axis	Description	Movement Example
Horizontal	Runs side-to-side through the body	Flexion and extension
Anteroposterior	Runs front-to-back through the body	Abduction and adduction
Longitudinal	Runs top-to-bottom through the body	Internal or external rotation

Relationship Between Planes and Axes

Every movement occurs in a plane and around an axis, and they are always perpendicular (at a 90-degree angle) to each other:



Photo A by RDNE Stock project, Photo B by Ketut Subiyanto, Photo C by Yogendra Singh, Pexels License

- Photo A (squats): Movements in the sagittal plane happen around the horizontal axis. When you do a squat, your knee joint moves in the sagittal plane, rotating around the horizontal axis.
- Photo B (jumping jacks): Movements in the frontal plane happen around the anteroposterior axis. When you perform a jumping jack, the arms and legs move in the frontal plane, rotating around the anteroposterior axis.
- Photo C: (pirouette spin): Movements in the transverse plane happen around the longitudinal axis. Rotational movements like pirouette spin move in the transverse plane, rotating around the longitudinal axis.

3.4 DIRECTIONAL TERMS

Directional terms help us describe where body parts are in relation to each other. Think of it like giving directions on a map, but instead of streets, we're talking about parts of the body. These terms always use **Anatomical Position** as the starting point.

Anterior/Posterior

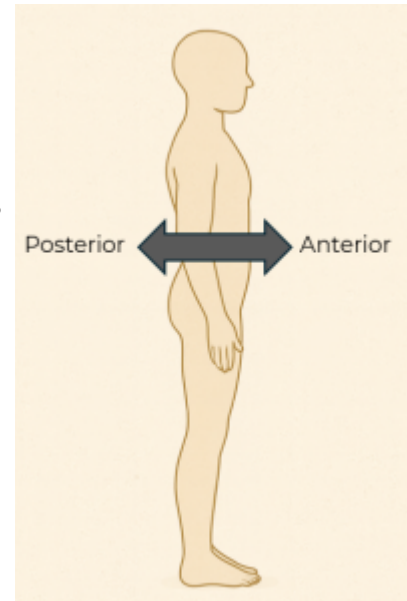
Anterior: Towards the front of the body

Posterior: Towards the back of the body

Examples:

- Your chest is anterior to your spine (your chest is in front of your spine)
- Your shoulder blades are posterior to your ribs (your shoulder blades are behind your ribs)

Think of it like this: If you're standing straight, your belly button is on the anterior side, and your back is on the posterior side.



Posterior/Anterior position. See Source below

Superior/Inferior

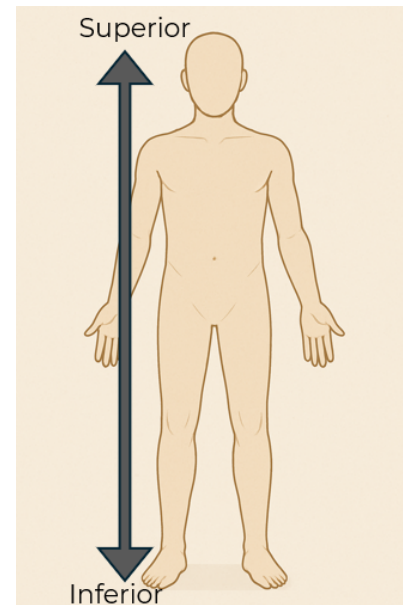
Superior: Above

Inferior: Below

Examples:

- Your head is superior to your shoulders (your head is above your shoulders)
- Your knees are inferior to your hips (your knees are below your hips)

Think of it like this: In a building, the second floor is superior to the first floor. The basement is inferior to the main floor.



Superior/Inferior position. See Source below

Medial/Lateral

Medial: Toward the middle of the body

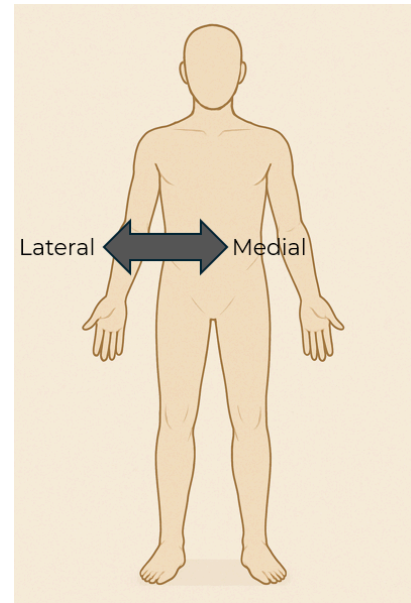
Lateral: Toward the sides of the body

Examples:

- Your nose is medial to your ears (your nose is closer to the middle of your face)
- Your shoulders are lateral to your chest (your shoulders are toward the sides of your body)

Think of it like this: Draw an imaginary line down the middle of your body — things closer to that line are medial, things farther from it are lateral.

Note: These terms are typically used to describe body parts located at the head, torso, and abdomen.



Lateral/Medial position. See Source below

Proximal/Distal

Proximal: Closer to where the arm or leg attaches to the body

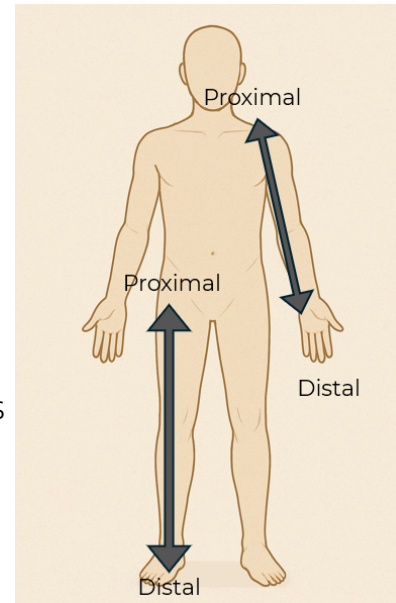
Distal: Farther away from where the arm or leg attaches to the body

Examples:

- Your shoulder is proximal to your hand (your shoulder is closer to your body)
- Your fingers are distal to your elbow (your fingers are farther from your body)

Think of it like this: If your arm is like a tree branch, the part of the branch near the trunk is proximal, and the leaves at the end are distal.

Note: These terms are exclusively used to describe body parts located between the shoulder joint and the hand, as well as the hip joint and the foot.



Proximal/Distal positioning. See [Source below](#)

Summary of Terms

Term	Meaning
Anterior	Front of the body
Posterior	Back of the body
Superior	Above
Inferior	Below
Medial	Toward the middle of the body
Lateral	Toward the sides of the body
Proximal	Closer to where the limb attaches
Distal	Farther from where the limb attaches

 Try This!

Let's test your knowledge of directional terms. Drag each term to its matching sentence.

Text Description

Drag the words into the correct boxes

1. 1. The chest is _____ to the spine.
2. 2. The nose is _____ to the ears.
3. 3. The arms are _____ to the torso.
4. 4. Shoulder blades are _____ to the ribs.
5. 5. The head is _____ to the shoulders
6. 6. The knees are _____ to the hips.
7. 7. Fingers are _____ to the elbow.
8. 8. The elbow is _____ to the wrist.

Possible answers:

- medial
- posterior
- proximal
- lateral
- superior
- anterior
- inferior
- distal

Correct Answers:

1. The chest is **anterior** to the spine.

2. The nose is **medial** to the ears.
3. The arms are **lateral** to the torso.
4. Shoulder blades are **posterior** to the ribs.
5. The head is **superior** to the shoulders
6. The knees are **inferior** to the hips.
7. Fingers are **distal** to the elbow.
8. The elbow is **proximal** to the wrist.

All images: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Create a generic, simplified image of the human body that is a faceless mannequin and represents a neutral anatomical model in both front and side profile. Modifications: Added text and arrows.

3.5 MOVEMENT TERMS

Try This!

The flashcards below contain terms that describe how joints and body parts move with one another. Most of these happen along planes and axes, and understanding them helps explain exercises, stretches, and even injuries. Click on each card to view the definition for each term.

Text Description

This activity contains a set of flashcards, which are described below.

Front of card:

1. Inversion/Eversion
2. Supination/Pronation
3. Flexion/Extension
4. Internal/External Rotation
5. Circumduction
6. Dorsiflexion/Plantarflexion
7. Abduction/Adduction

Back of card:

1. Inversion: Turning the sole of the foot inward (toward the midline)/Eversion: Turning the sole of the foot outward (away from the midline)/Plane: Frontal/Axis: Anteroposterior/Example: Rolling your ankle inward (inversion) and rolling your ankle outward (eversion).
2. Supination: Rotating the forearm so the palm faces upward/Pronation: Rotating

the forearm so the palm faces downward/Plane: Traverse/Axis: Longitudinal/
Example: Holding a bowl of soup with your palm up (supination) and facing your palm down (pronation).

3. Flexion: Bending a joint, decreasing the angle between two body parts/Extension: Straightening a joint, increasing the angle between two body parts/Plane: Sagittal/Axis: Horizontal/Example: Biceps curl.
4. Internal Rotation: Rotating a body part toward the midline/Rotating a body part away from the midline/Plane: Traverse/Axis: Longitudinal/Example: Turning your hip or shoulder inward or outward.
5. Circumduction: Making a circular movement at a joint, combining flexion, extension, abduction, and adduction/Plane: Multiple/Axis: Multiple/Example: Making big circles with you arm or leg or winding up your arm like a softball pitcher.
6. Dorsiflexion: Flexing the ankle so the toes point upward/Plantarflexion: Pointing the toes downward/Plane: Sagittal/Axis: Horizontal/Example: Pulling your toes toward your shin (dorsiflexion) and then pressing your foot down like pushing a gas pedal (Plantarflexion).
7. Abduction: Moving a body part away from the midline of the body (Tip: taking away or being “abducted”)/Adduction: Moving a body part toward the midline/Plane: Frontal/Axis: Anteroposterior/Example: Jumping jacks.

Specific Shoulder Movements

Elevation/Depression

- **Elevation:** Lifting the shoulder upward
- **Depression:** Moving the shoulder downward
- Plane: Frontal
- Axis: None
- Example: Shrugging your shoulders (elevation) and relaxing your shoulders (depression)



Photo by MART PRODUCTION,
Pexels License

Protraction/Retraction

- **Protraction:** Moving the shoulder forward (away from the spine)
- **Retraction:** Pulling the shoulder backward (toward the spine)
- Plane: Transverse
- Axis: none
- Example: Rounding your shoulders forward (protraction) and squeezing your shoulder blades together (retraction)

Summary of Terms

Joint	Movements Possible
Knee	Flexion, Extension
Shoulder	Flexion, Extension, Abduction, Adduction, Circumduction, Internal/External Rotation, Elevation, Depression, Protraction, Retraction
Hip	Flexion, Extension, Abduction, Adduction, Circumduction, Internal/External Rotation
Elbow	Flexion, Extension
Wrist	Flexion, Extension, Supination, Pronation
Ankle	Dorsiflexion, Plantarflexion, Inversion, Eversion
Spine	Flexion, Extension

3.6 CHAPTER SUMMARY

Key Takeaways

- Anatomical terminology is like a language built from prefixes and suffixes that help decode complex terms.
- Anatomical position is the universal starting point used to describe body structure, movement, and direction.
- Directional terms (e.g., anterior, superior, distal) describe where body parts are located in relation to one another.
- The body can be divided into three main planes (sagittal, frontal, transverse) and axes (horizontal, anteroposterior, longitudinal) to describe movement.
- Movements happen in a specific plane and around a specific axis, which are always perpendicular to each other.
- Common joint actions like flexion, extension, abduction, and rotation are used to describe how body parts move.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into key takeaways.

 Key Terms

- **Abduction:** Movement away from the body's midline.
- **Adduction:** Movement toward the body's midline.
- **Anatomical Position:** Standard reference posture: standing upright, facing forward, arms at sides, palms forward.
- **Anterior:** Toward the front of the body.
- **Anteroposterior Axis:** Front-to-back axis; allows abduction/adduction.
- **Circumduction:** Moving a limb in a circular motion.
- **Depression:** Lowering a body part.
- **Distal:** Further from the attachment point of a limb.
- **Dorsiflexion:** Raising the toes toward the shin.
- **Elevation:** Raising a body part.
- **Eversion:** Turning the sole of the foot outward.
- **Extension:** Straightening a joint; increasing the angle.
- **External Rotation:** Rotating away from the midline.
- **Flexion:** Bending a joint; decreasing the angle.
- **Frontal Plane:** Divides the body into front and back halves.
- **Horizontal Axis:** Side-to-side axis; allows flexion/extension.
- **Inferior:** Below.
- **Internal Rotation:** Rotating toward the midline.
- **Inversion:** Turning the sole of the foot inward.
- **Lateral:** Away from the midline.
- **Longitudinal Axis:** Vertical axis; allows rotation.
- **Medial:** Toward the midline.
- **Plantarflexion:** Pointing the toes downward.
- **Posterior:** Toward the back of the body.
- **Pronation:** Rotating the palm/sole downward.
- **Protraction:** Moving a body part forward (away from the spine).

- **Proximal:** Closer to the attachment point of a limb.
 - **Retraction:** Moving a body part backward (toward the spine).
 - **Sagittal Plane:** Divides the body into left and right halves.
 - **Superior:** Above.
 - **Supination:** Rotating the palm/sole upward.
 - **Transverse Plane:** Divides the body into upper and lower halves.
-

OpenAI. (July 22nd, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Create a simple list of key terms and their definitions in the content provided.

3.7 KNOWLEDGE CHECK

Knowledge Check

Text Description:

1. **Which term describes movement away from the midline of the body?**
 - Adduction
 - Flexion
 - Abduction
 - Rotation
2. **What plane divides the body into top and bottom halves?**
 - Frontal Plane
 - Sagittal Plane
 - Transverse Plane
 - Longitudinal Plane
3. **If you rotate your arm so your palm faces upward, which movement is this?**
 - Pronation
 - Supination
 - Eversion
 - Elevation
4. **What axis allows rotational movement such as turning your head?**

- Anteroposterior Axis
- Horizontal Axis
- Longitudinal Axis
- Lateral Axis

5. **Which directional term means “toward the front of the body”?**

- Posterior
- Anterior
- Inferior
- Medial

6. **What does the prefix “inter-” mean in anatomical terminology?**

- Within
- Under
- Between
- Above

7. **Which movement occurs when you point your toes downward?**

- Dorsiflexion
- Plantarflexion
- Flexion
- Retraction

Correct Answers:

1. Abduction
2. Transverse Plane
3. Supination
4. Longitudinal Axis
5. Anterior

6. Between
7. Plantarflexion

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 4: BONES

Chapter Overview

4.0 Learning Objectives

4.1 The Human Skeleton

4.2 Types of Bone

4.3 Bones of the Axial Skeleton

4.4 Bones of the Appendicular Skeleton

4.5 Chapter Summary

4.6 Knowledge Check

4.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Identify and describe the major functions of the skeletal system and explain how it supports overall body function.
- Classify bones by shape and provide examples of each type.
- Distinguish between the axial and appendicular skeleton and list the main bones found in each division.
- Locate and name key bones of the skull, spine, ribcage, upper limb, and lower limb using appropriate anatomical terminology.
- Explain the role of specific bones in the movement, support, and protection of vital organs.
- Use anatomical language to describe the structure and location of major bones in relation to body regions and other bones.

4.1 THE HUMAN SKELETON



“Human Skeleton Model” by Tima Miroshnichenko, Pexels License

The human skeleton is the body’s internal framework, giving us shape, protecting vital organs, enabling movement, and even producing blood cells. Without it, we’d be little more than a floppy pile of muscles and organs.

Adults typically have 206 bones, while babies are born with around 270. As we grow, some of these bones fuse together, particularly in the skull and spine. Interestingly, the smallest bone in the human body is the stapes, found in the ear and smaller than a grain of rice. In contrast, the largest bone is the **femur**, or thigh bone, which plays a key role in supporting our body weight and facilitating movement.

Functions of the Skeletal System

- **Support:** Holds the body upright and provides structure
- **Protection:** Shields vital organs (e.g., skull protects the brain, ribs protect the heart)
- **Movement:** Bones act as levers — muscles pull on bones to create movement
- **Blood Cell Production:** **Bone marrow** makes red and white blood cells
- **Mineral Storage:** Bones store calcium and other minerals needed for body function

Example: When you run, your leg bones support your weight, your joints help movement, and muscles pull on your bones to create motion.

4.2 TYPES OF BONE

Try This!

Bones come in different shapes and sizes, depending on their role in the body. There are four main types of bones, each designed for specific functions like movement, protection, or support. Click on each icon below to learn more.

Text Description

Long Bones:

- Longer than they are wide
- Mostly found in the arms and legs
- Provide strength, support, and are essential for movement

Examples:

- Femur (thigh bone)
- Humerus (upper arm bone)
- Tibia and Fibula (lower leg)
- Radius and Ulna (forearm)

Quick Tip: Long bones typically act like levers. Muscles pull on them to create movement.

Short Bones:

- About as wide as they are long — roughly cube-shaped
- Provide stability and support, but allow limited movement

Examples:

- Carpals (wrist bones)
- Tarsals (ankle bones)

Quick Tip: Think of short bones like building blocks. They help create stable but highly moveable areas like your wrists and ankles.

Flat Bones:

- Thin, flat, and often slightly curved
- Protect vital organs and provide large surfaces for muscle attachment

Examples:

- Skull bones
- Ribs
- Sternum (breastbone)
- Scapula (shoulder blade)

Quick Tip: Flat bones often act like shields, protecting your brain, heart, and lungs.

Irregular Bones:

- Have complex, unique shapes
- Often protect nervous tissue or provide multiple points for muscle attachment

Examples:

- Vertebrae (spinal bones)
- Pelvis
- Certain facial bones

Quick Tip: Irregular bones don't fit into other categories. They have special shapes for special jobs, like supporting the spine or forming your face.

4.3 BONES OF THE AXIAL SKELETON

The **axial skeleton** forms the central core of the body — it includes the skull, spine, ribs, and sternum. Its main jobs are to protect vital organs (like the brain, heart, and lungs), provide support, and anchor muscles.

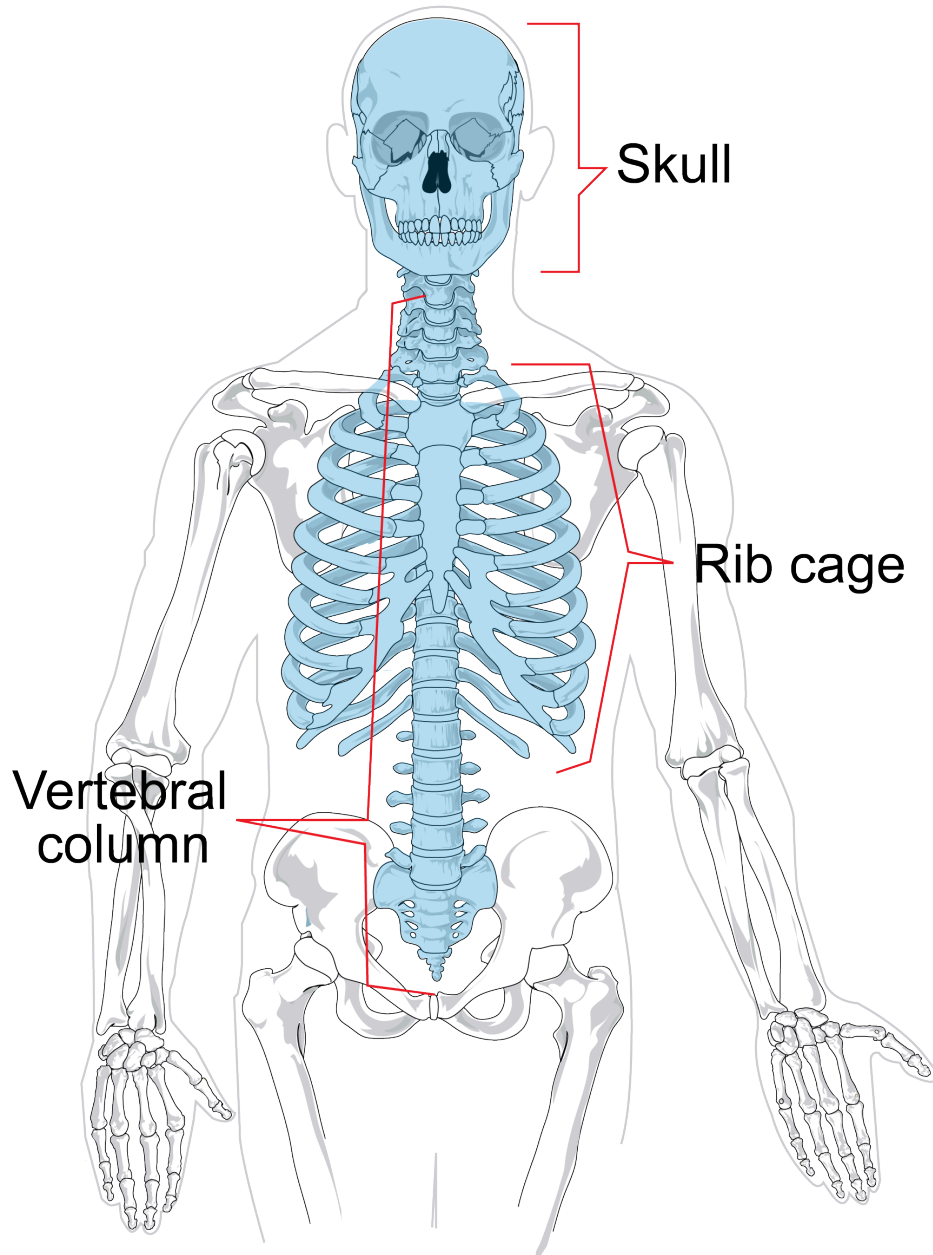
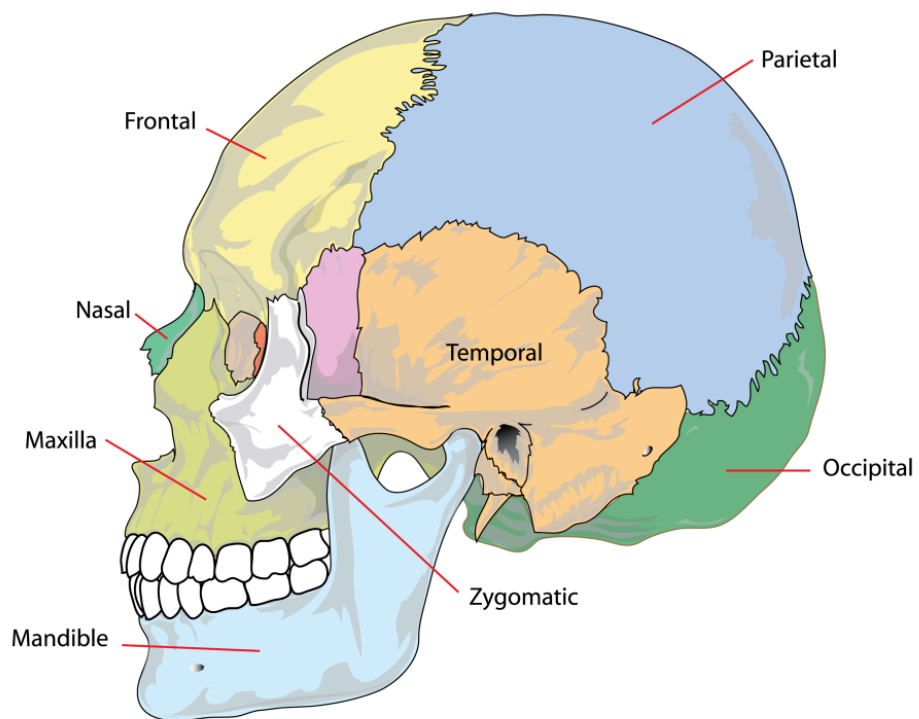


Image by Lady of Hats, Public Domain Modified: some labels removed

Bones of the Axial Skeleton

Skull



"Human skull side simplified" by Lady of Hats, Public Domain Modified by Alkd
Further modifications: some labels removed

The skull protects the brain and forms the shape of the head and face. The bones you need to know are:

- **Frontal:** Forehead: Front part of the skull
- **Parietal:** Top and upper sides of the skull
- **Temporal:** Lower sides of the skull near the ears
- **Nasal:** Bridge of the nose
- **Zygomatic:** Cheekbones
- **Maxilla:** Upper jaw; holds the upper teeth
- **Mandible:** Lower jaw; the only movable skull bone, helps with chewing
- **Occipital:** Back and base of the skull; contains a hole for the spinal cord (foramen magnum)

The Rib Cage

The rib cage protects the heart and lungs. It includes:

- **Sternum:** Flat bone in the center of the chest (breastbone)
- **12 pairs of Ribs:**
 - **7 True Ribs:** Attach directly to sternum (numbered 1 to 7)
 - **3 False Ribs:** Attach indirectly via cartilage (numbered 8 to 10)
 - **2 Floating Ribs:** Do not attach to sternum at all (numbered 11 and 12)

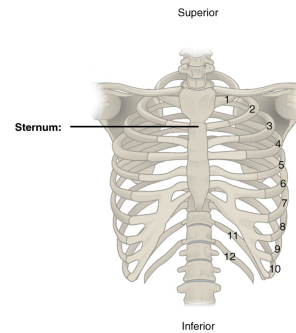


Image by OpenStax, CC BY 4.0
 Modified: cropped and some labels removed

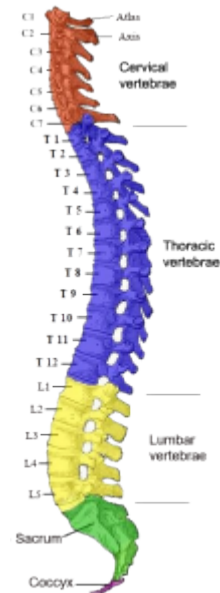
The Vertebral Column (Spine)

The spine supports the body, protects the spinal cord, and allows movement. It has three main regions:

- **Cervical Vertebrae:** 7 bones in the neck area (C1 to C7)
- **Thoracic Vertebrae:** 12 bones in the upper/mid-back; ribs attach here (T1 to T12)
- **Lumbar Vertebrae:** 5 large, strong bones in the lower back (L1 to L5)

Quick Tip:

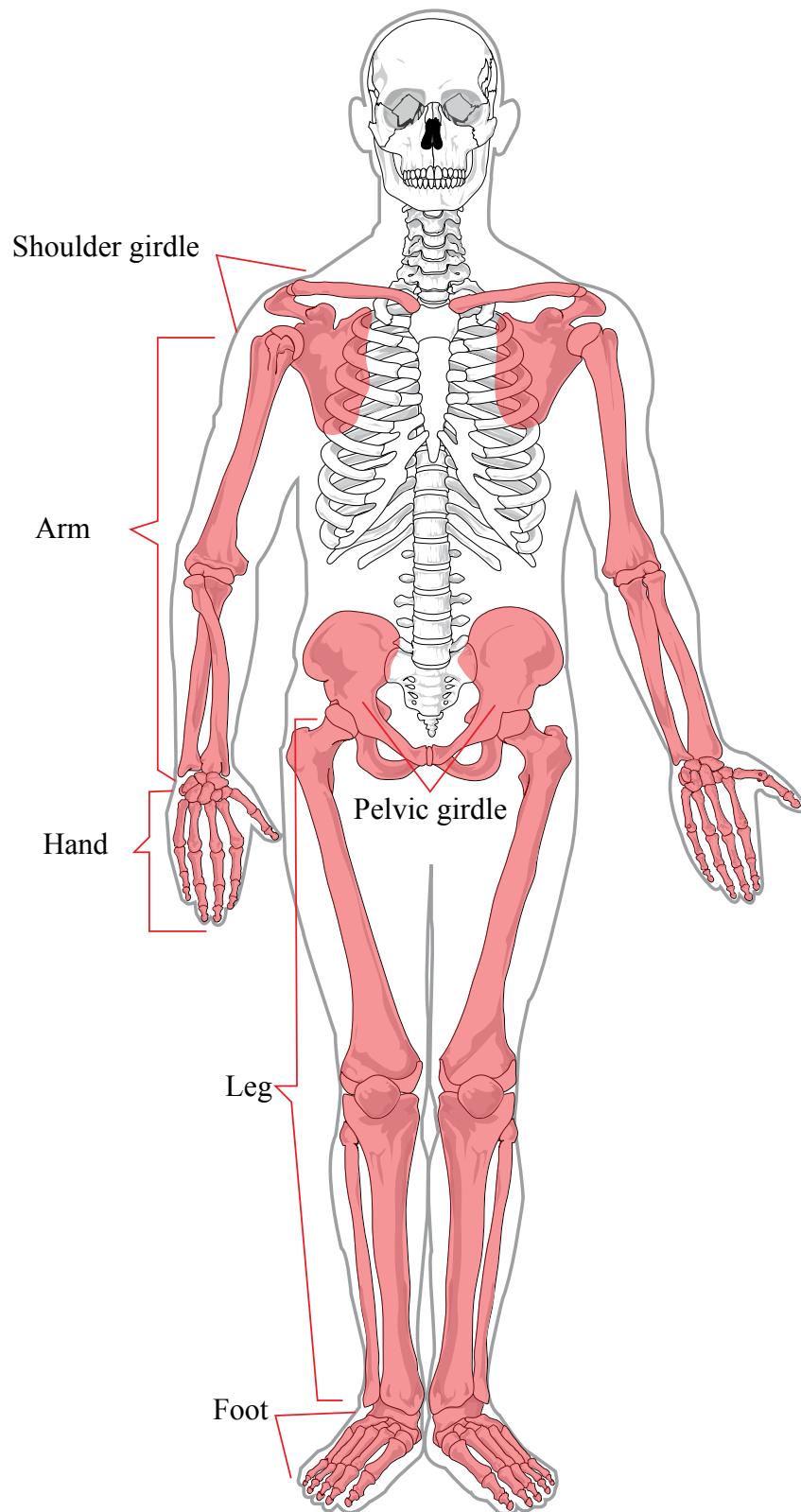
- “Breakfast at 7” = 7 Cervical Vertebrae
- “Lunch at 12” = 12 Thoracic Vertebrae
- “Dinner at 5” = 5 Lumbar Vertebrae



“Vertebral Column” by RWhitwam, CC BY-SA 4.0

4.4 BONES OF THE APPENDICULAR SKELETON

The **appendicular skeleton** includes 126 bones that form the limbs, shoulders, and hips. These bones allow for movement, provide structure to the body, and protect important areas like the reproductive organs and joints.



Upper Bones of the Appendicular Skeleton

Bones of the Shoulder

- **Clavicle:** Known as the collarbone, it connects the sternum (chest bone) to the scapula (shoulder blade). It acts like a strut, keeping the shoulders apart and stable.
- **Scapula:** The shoulder blade, a large, flat, triangular bone on the upper back. It provides attachment points for many muscles and forms part of the shoulder joint.

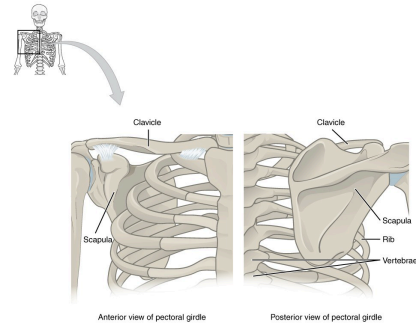


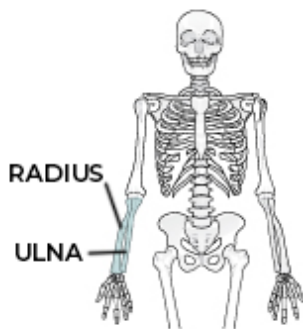
Image by OpenStax, CC BY 4.0 Modifications: Cropped and some labels removed.



Humerus

The long bone of the upper arm connects the shoulder to the elbow. It is involved in many movements, including lifting and throwing.

Image by OpenStax, CC BY 4.0 Modified: cropped and label added

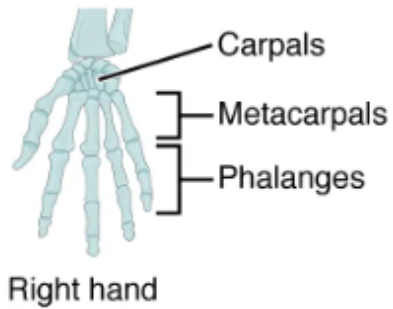


Radius and Ulna

Radius: One of the two forearm bones, located on the thumb side. It rotates around the ulna, allowing your palm to turn up (supination) or down (pronation).

Ulna: The second forearm bone, located on the pinky side. It forms the point of your elbow and works with the radius to enable wrist and arm movements.

Image by OpenStax, CC BY 4.0 Modified: cropped and labels added



Metacarpals

The five bones in the palm of the hand connect the wrist (**carpals**) to the fingers (**phalanges**). They support hand structure and movement.

Image by OpenStax, CC BY 4.0
Modified: cropped and label added

Lower Bones of the Appendicular Skeleton

The Pelvic Girdle

The **pelvis** is the large, bowl-shaped structure at the base of the spine. It connects the spine to the lower limbs and supports body weight when standing. Made of three fused bones:

- **Ilium:** The large, upper portion of the pelvis. You can feel the iliac crest when you place your hands on your hips.
- **Ischium:** The lower, back portion of the pelvis — the part you sit on.
- **Pubis:** The front portion of the pelvis, where the two sides join together at the pubic symphysis, a cartilage joint.

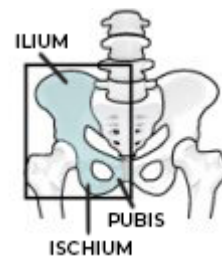


Image by OpenStax,
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cropped and labels
added

Femur

The femur, also known as the thigh bone, is the longest and strongest bone in the body. It connects the hip to the knee and supports most of your body weight while you are standing, walking, and running.

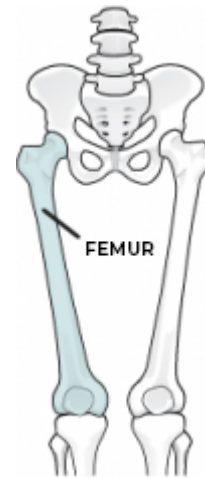


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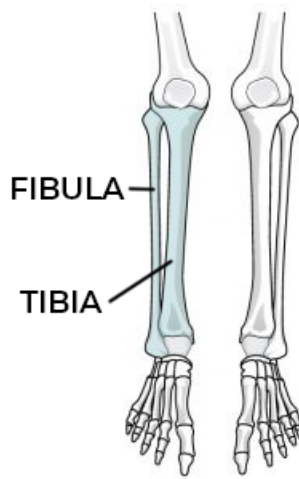


Image by OpenStax, CC BY 4.0
Modified: crop and labels added

Tibia and Fibula

Tibia: Known as the shin bone, the larger and stronger of the two lower leg bones. It bears most of the body's weight and connects the knee to the ankle.

Fibula: The thinner bone running beside the tibia. It provides support and stability but bears less weight. It also forms part of the ankle joint.

The Foot Bones

Calcaneus: The heel bone, the largest bone of the foot. It forms the base of the heel and absorbs shock during walking, running, and jumping.

Talus: Sits on top of the calcaneus and connects the foot to the tibia and fibula. It forms the ankle joint, allowing foot movement up and down.

Metatarsals: The five long bones in the middle of the foot, connecting the ankle bones (**tarsals**) to the toes. They help support the arch and allow for walking and balance.

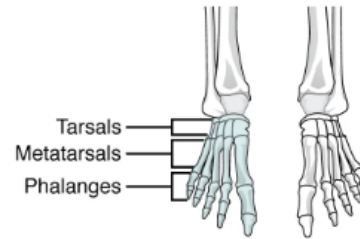


Image by OpenStax, CC BY 4.0
Modified: cropped

4.5 CHAPTER SUMMARY

Key Takeaways

- **The skeletal system provides essential structure and function:** It supports the body, protects vital organs (like the brain and heart), enables movement through joints and muscle attachments, produces blood cells in bone marrow, and stores minerals such as calcium.
 - **There are four major bone types, each with specific roles:** Long bones (e.g., femur, humerus) aid in movement, short bones (e.g., carpals, tarsals) offer stability, flat bones (e.g., ribs, skull) protect organs, and irregular bones (e.g., vertebrae, pelvis) have complex shapes for specialized functions.
 - **The skeleton is divided into two parts – the axial and appendicular skeleton.** The axial skeleton includes the skull, spine, and ribcage and provides central support and protection. The appendicular skeleton includes limbs, shoulders, and pelvis and is responsible for movement and interaction with the environment.
 - **Each bone in the body has a specific location and purpose:** For example, the femur supports body weight, the radius and ulna control forearm rotation, and the vertebrae protect the spinal cord while allowing flexibility.
 - **Bones grow and change over time:** Babies are born with approximately 270 bones, which fuse into 206 bones by adulthood, particularly in the skull and spine, reflecting the body's development and specialization.
-

OpenAI. (July 22nd, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into five key takeaways.

Key Terms

- **Appendicular Skeleton:** Bones of the limbs and girdles (shoulders, hips) that attach to the axial skeleton.
- **Axial Skeleton:** Central part of the skeleton: skull, spine, ribs, and sternum.
- **Bone Marrow:** Soft tissue inside bones that produces red and white blood cells.
- **Carpals:** 8 small wrist bones.
- **Calcaneus:** Heel bone; supports weight and absorbs shock.
- **Cervical Vertebrae:** 7 bones in the neck region (C1–C7).
- **Clavicle:** Collarbone; connects the sternum and scapula.
- **False Ribs:** Next 3 pairs that attach to the sternum indirectly.
- **Femur:** Thigh bone; longest and strongest bone in the body.
- **Fibula:** Slender bone beside the tibia; helps stabilize ankle and lower leg.
- **Flat Bones:** Thin and often curved; protect organs and allow muscle attachment (e.g., ribs, sternum, skull).
- **Floating Ribs:** Last 2 pairs that do not attach to the sternum.
- **Frontal Bone:** Forehead and front part of the skull.
- **Humerus:** Upper arm bone; connects shoulder to elbow.
- **Ilium:** Upper part of the pelvis; has the iliac crest.
- **Irregular Bones:** Complex shapes; serve specialized purposes (e.g., vertebrae, pelvis, facial bones).
- **Ischium:** Lower back part of the pelvis; what you sit on.
- **Long Bones:** Longer than they are wide; used for movement and support (e.g., femur, humerus).

- **Lumbar Vertebrae:** 5 strong lower back bones.
- **Mandible:** Lower jawbone; only moveable skull bone, used for chewing.
- **Maxilla:** Upper jawbone; holds upper teeth.
- **Metacarpals:** 5 hand bones connecting wrist to fingers.
- **Metatarsals:** 5 long bones in the middle of the foot.
- **Nasal Bone:** Bridge of the nose.
- **Occipital Bone:** Back and base of the skull; has an opening for the spinal cord.
- **Parietal Bone:** Top and upper sides of the skull.
- **Pelvis:** Large basin-shaped structure that connects spine to legs and supports weight.
- **Phalanges:** Finger and toe bones.
- **Pubis:** Front part of the pelvis where the two sides join.
- **Radius:** Forearm bone on the thumb side; rotates to allow wrist movement.
- **Scapula:** Shoulder blade; large flat bone that connects with the humerus.
- **Short Bones:** Cube-shaped; provide stability and support with limited motion (e.g., carpals, tarsals).
- **Skeletal System:** The internal framework of the body; supports, protects, enables movement, produces blood cells, and stores minerals.
- **Sternum:** Flat chest bone (breastbone) in the centre of the ribcage.
- **Talus:** Bone at the top of the foot; part of the ankle joint.
- **Tarsals:** 7 small ankle bones.
- **Tibia:** Shin bone; larger and weight-bearing lower leg bone.
- **Temporal Bone:** Lower sides of the skull, near ears.
- **Thoracic Vertebrae:** 12 mid-back bones that attach to the ribs.
- **True Ribs:** First 7 pairs of ribs that attach directly to the sternum.
- **Ulna:** Forearm bone on the pinky side; forms the elbow's point.
- **Zygomatic Bone:** Cheekbone.

chat. Prompt: Create a simple list of key terms and their definitions in the content provided.

4.6 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. **Which of the following is a function of the skeletal system?**

- Producing hormones
- Regulating body temperature
- Supporting and protecting the body
- Digesting nutrients

2. **What type of bone is the femur classified as?**

- Irregular bone
- Long bone
- Short bone
- Flat bone

3. **Which bones make up the axial skeleton?**

- Arms and legs
- Skull, ribs, spine, sternum
- Pelvis and scapula
- Hands and feet

4. **What is the function of the bone marrow?**

- Protects organs

- Stores calcium
- Produces blood cells
- Connects muscles to bones

5. **Which bone is known as the collarbone?**

- Scapula
- Radius
- Clavicle
- Sternum

6. **How many cervical vertebrae are in the human spine?**

- 5
- 7
- 12
- 14

7. **What is the long bone of the upper arm, connecting the shoulder to the elbow?**

- Ulna
- Humerus
- Femur
- Radius

Correct Answers:

1. Supporting and protecting the body
2. Long bone
3. Skull, ribs, spine, sternum
4. Produces blood cells
5. Clavicle

6. 7
7. Humerus

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 5: MUSCULAR SYSTEM

Chapter Overview

5.0 Learning Objectives

5.1 “Mind Muscle”

5.2 What are Muscles?

5.3 Muscular Attachments and Contraction

5.4 Naming Muscles

5.5 Muscles of the Neck

5.6 Muscles of the Scapula

5.7 Muscles of the Thorax and Abdomen

5.8 Muscles of the Upper Limb

5.9 Muscles of the Back

5.10 Muscles of the Hip

5.11 Muscles of the Upper Leg

5.12 Muscles of the Lower Leg

5.13 Chapter Summary

5.14 Knowledge Check

5.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Define what a muscle is and what it is made up of.
- Identify and explain the three types of muscle tissue.
- Explain how a muscle attaches to bone and how this is associated with muscular contraction.
- Identify and describe the location, name, and action of musculature throughout the human body.

5.1 "MIND MUSCLE"



Picture This...

If you were to close your eyes and explain the first thing that comes to mind when you hear the word “muscles,” I am sure a variety of things might pop into your head. It may be the image of a large bodybuilder stepping on stage and presenting their physique in front of a crowd of spectators and a few judges, maybe it is an image of Arnold Schwarzenegger flexing his biceps on a beach in the 1970s, or maybe it is something similar to the photo on the right. While these are all exemplifications of “muscles”, there is much more than meets the eye when it comes to the muscular system.



“Hypertrophy” by OpenStax, CC BY 4.0

In this chapter, we will examine the definitions, structures, and concepts associated with muscles, in particular skeletal muscle (more on that to come). We also investigate muscular anatomy and the naming, identification, and action(s) of musculature throughout the human body.

5.2 WHAT ARE MUSCLES?

Muscle is one of four main tissue types in the human body (Nervous, Connective, and Epithelial, to name the other three). They are a culmination of hundreds, thousands, or even hundreds of thousands of muscle cells (aka muscle fibres) that contract and relax to allow us to digest food, breathe, speak, blink, pump blood throughout our body, and produce movement.

Types of Muscle Tissue

Typically, when we think about muscle, we think of skeletal muscle, such as our quadriceps or biceps; however, muscle tissue also exists as cardiac and smooth muscle. Let's explore their differences by clicking on each icon below.

Text Description

Cardiac Muscle:

- Found exclusively in the heart
- Responsible for contracting to eject blood from the heart and begin circulation
- Involuntary (regulated by the autonomic nervous system)
- Striated (striped and aligned microscopic appearance)

Skeletal Muscle:

- A muscle that attaches to a bone
- The most prevalent type of muscle in the human body (makes up 30-40% of body weight)
- Voluntary (i.e., you have conscious control of skeletal muscle contraction)
- Striated (striped and aligned microscopic appearance)

Smooth Muscle:

- Surrounds the body's internal organs (i.e., blood vessels, digestive tract)
- Contracts slowly for longer durations
- Involuntary (i.e., you have no conscious control of smooth muscle contraction)

Voluntary vs Involuntary Contractions

While sitting there reading this chapter, you can differentiate voluntary vs involuntary contractions by asking yourself: “Can I purposefully contract the muscle?”. Try contracting your blood vessels or small intestine; you can't; therefore, they are involuntary. Try contracting your heart muscles; you can't, therefore, they are also involuntary. Now try contracting your biceps brachii or your hip flexor group; you can, therefore, they are voluntary.

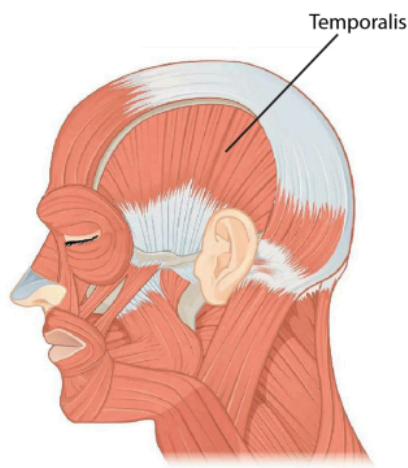
Of the three main types of muscle previously mentioned, skeletal muscle is responsible for generating the force required to produce voluntary human movement. You will learn more about skeletal muscle anatomy in Chapter 11.

“10.2 Skeletal Muscle” from Anatomy & Physiology by Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, OSU OERU & OpenStax is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License, except where otherwise noted.

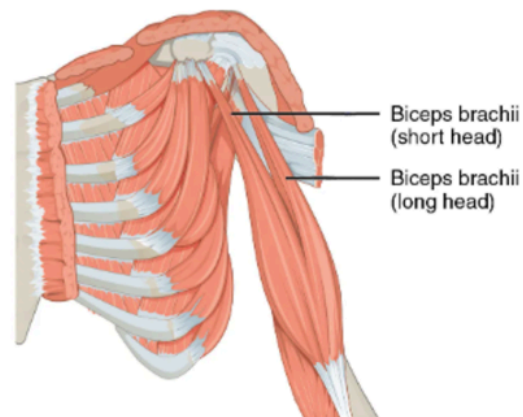
5.3 MUSCULAR ATTACHMENTS AND CONTRACTION

Skeletal muscles can attach themselves to bone by direct or indirect attachment.

- **Direct** muscular attachment includes the outer membranes of a muscle attaching themselves to the outer membranes of a bone (i.e., temporalis, trapezius).
- **Indirect** muscular attachment is more common and includes muscles attaching themselves to bones via tendons (Note: this will be discussed in more detail in Chapter 11).



Direct attachment



Indirect attachment

Examples of direct and indirect attachment by OpenStax, CC BY 4.0 Modified: cropped

Regardless of the attachment type, each skeletal muscle has at least two points of attachment with the skeletal system, known as the **origin** and the **insertion**.

Origin	Insertion
• The point of attachment is found at the fixed (more stationary or less movable) location. • Typically located at the more medial or proximal attachment site	• The point of attachment is found at the mobile (more movable or less stationary) location. • Typically located at the more lateral or distal attachment site



Video: Origins and Insertions

Watch the video “Origins and Insertions” by The Noted Anatomist [2:38], which is licensed under the Standard YouTube License. *The transcript and closed captions are available on YouTube.*

Muscle Contraction

When conceptualizing the process of muscular contraction, it is important to note that muscles can only “pull” on bone through their direct or indirect attachment site at the insertion; they can never “push”.

The extent and force of this “pulling” (muscular contraction) relative to a load (whether bodyweight or some external load) can produce these three distinct types of skeletal muscle contraction:

Concentric

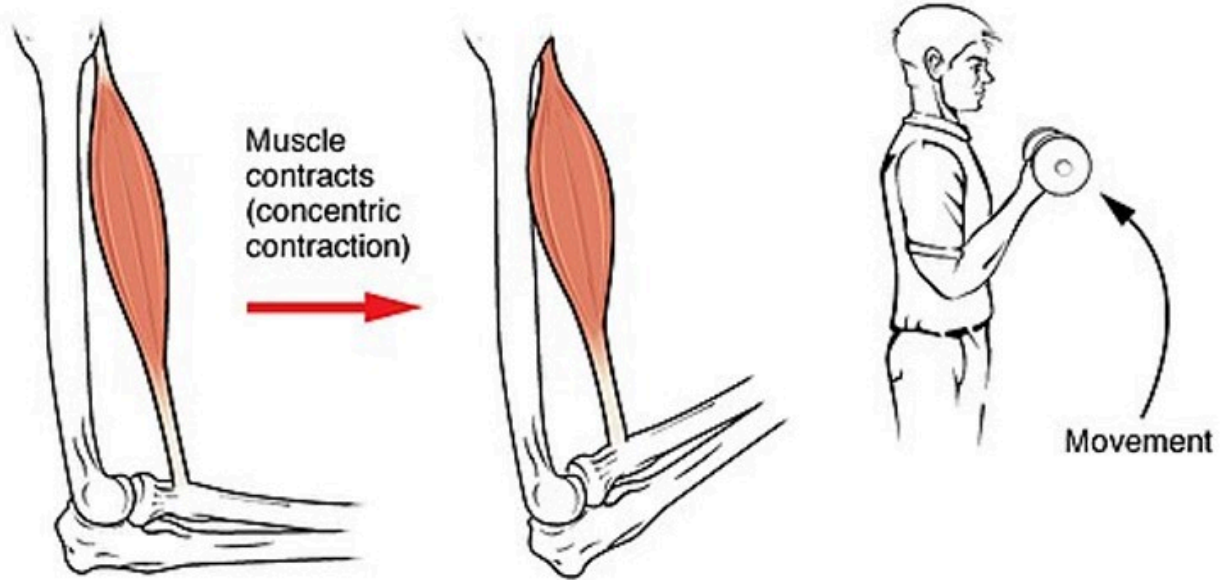


Illustration by OpenStax, CC BY 4.0 Modified: Cropped

Concentric Contraction: Shortening of muscle fibres. (For example, the biceps brachii move a dumbbell so that the joint angle at the elbow decreases.)

Eccentric

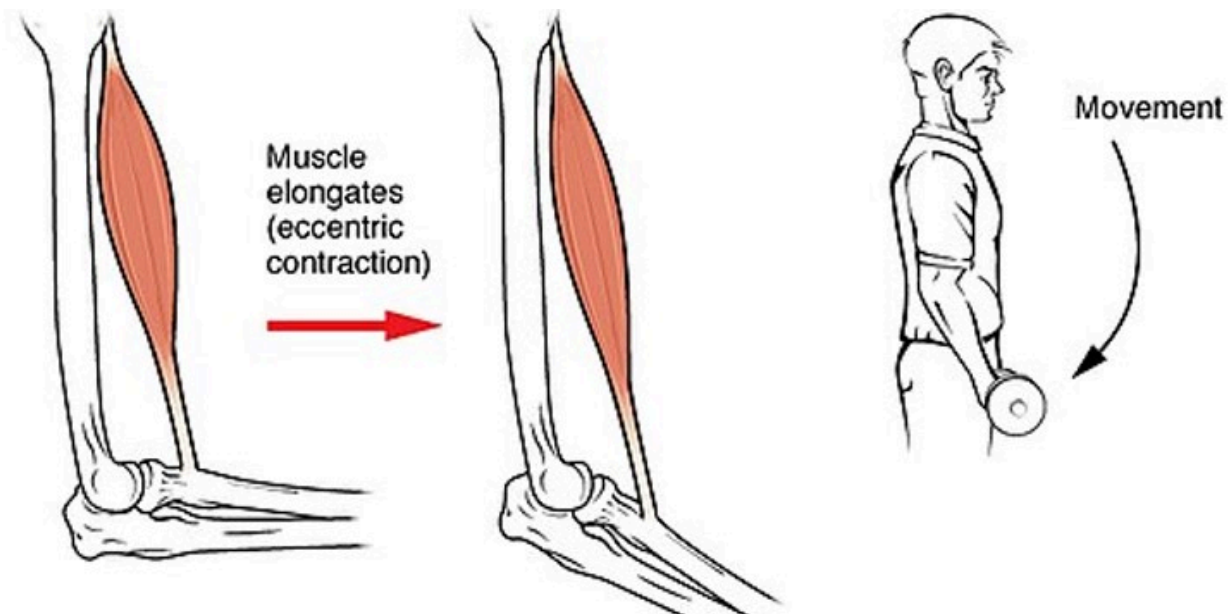


Illustration by OpenStax, CC BY 4.0 Modified: Cropped

Eccentric Contraction: Lengthening of muscle fibres. (For example, the biceps brachii lowers a dumbbell so that the joint angle at the elbow increases.)

Isometric

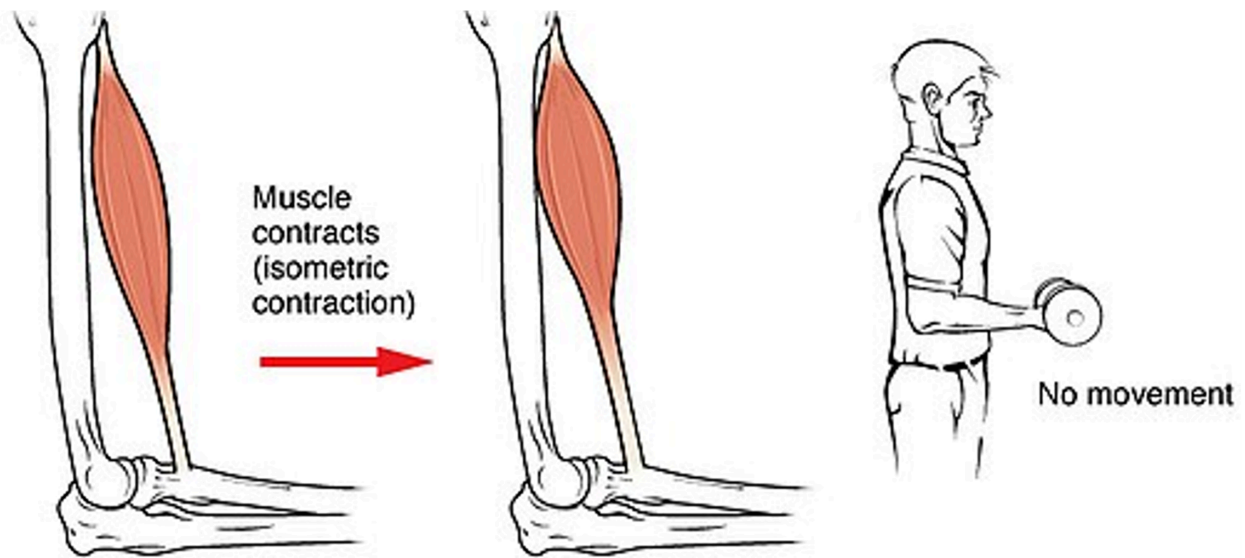


Illustration by OpenStax, CC BY 4.0 Modified: Cropped

Isometric Contraction: Static hold of muscle fibres. (For example, the biceps brachii is statically holding a dumbbell such that the joint angle at the elbow is unchanging).

Regardless of contraction type, skeletal muscles are typically arranged as pairs that share opposing actions, which are called antagonist pairs. Although numerous muscles may be recruited for a specific action, the principal or primary mover producing this action is referred to as the **agonist** muscle. Conversely, a muscle with the opposite action of the primary mover is referred to as the **antagonist** and is responsible for maintaining limb position and controlling movement.



Video: Your Muscle Screams in Agony

This video explains the agonist-antagonist relationship between the biceps and triceps brachii muscles well. It explains that as the agonist muscle contracts and shortens, the antagonist muscle relaxes and lengthens to facilitate movement.

“Your Muscle Screams in Agony” by Free Animated Education [1:53], which is licensed under the Standard YouTube License. *The transcript and closed captions are available on YouTube.*

The muscles that are activated during movement but are not included as part of the antagonist pair can be referred to as **stabilizer** or **synergist** muscles, which both aid in the facilitation of movement but have the following distinct roles:

Stabilizer	Synergist
A muscle that provides support and holds joints in place during movement. (ex, core musculature during a sprint or rotator cuff muscles during an overhead press).	Assist the agonist muscle by aiding in force production or by stabilizing the origin or insertion of the agonist muscle. (ex, biceps brachii during a pull-up or triceps brachii during a bench press).

“10.4 Nervous System Control of Muscle Tension” from Anatomy & Physiology by Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, OSU OERU & OpenStax is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License, except where otherwise noted.

“11.1 Describe the roles of agonists, antagonists and synergists” from Anatomy & Physiology by Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, OSU OERU & OpenStax is

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5.4 NAMING MUSCLES

Muscles are typically named based on the Latin or Greek root words that describe the action, location, direction of fibres, number of heads, and/or points of attachment for a given muscle. Rather than simply memorizing the names of the muscles that will be introduced later in this chapter, it is best practice to understand why they are named the way they are. This method will provide further insight into describing where the muscle is located, what it does, where it attaches, etc. and will provide a much more comprehensive understanding of muscular anatomy. The chart below explains the naming of musculature in more detail.

Naming Convention	Examples
Muscle Action	Adductor Magnus, where Adductor refers to the action/movement the muscle produces when contracted.
Fibre Direction	Rectus Abdominus, where Rectus refers to muscle fibres oriented vertically.
Muscle Location	Tibialis Anterior, where Anterior refers to the muscle's location on the anterior aspect of the body.
Number of Heads/Divisions	Triceps Brachii, where "Tri-" refers to the muscles' 3 heads (lateral, long, & medial).
Muscle Shape	Deltoids, where "delt-" refers to the Greek letter <i>delta</i> , describing the muscle's triangular shape.
Muscle Attachment	Sternocleidomastoid, referring to the muscles' attachments at the "sterno-" (sternum), "cleido-" (clavicle), and "mastoid" (mastoid process of the skull).

When working through each muscle in this chapter, try breaking down each component of the name into one of these categories, almost as if to solve the puzzle embedded in each muscle's name.



Video: How are Muscles Named?

The following video reiterates the naming of musculature and includes many muscles which are not included in the course material.

Video: “How are muscles named? – Terminology – Human Anatomy | Kenhub” by Kenhub – Learn Human Anatomy [11:31] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

5.5 MUSCLES OF THE NECK

Sternocleidomastoid

Action: Forward & lateral neck flexion and rotation of the neck

The sternocleidomastoid is named for its three bony attachments and can be broken down as follows:

- Sterno: Due to its attachment at the sternum
- Cleido: Due to its attachment at the clavicle
- Mastoid: Due to its attachment at the mastoid process of the skull

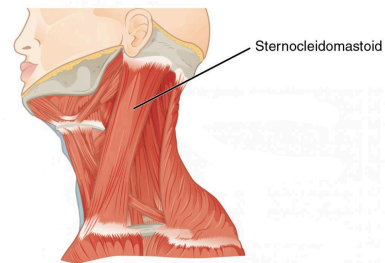


Image by OpenStax, CC BY 4.0
Modified text labels

5.6 MUSCLES OF THE SCAPULA

Muscles of the Scapula (Rotator Cuff)

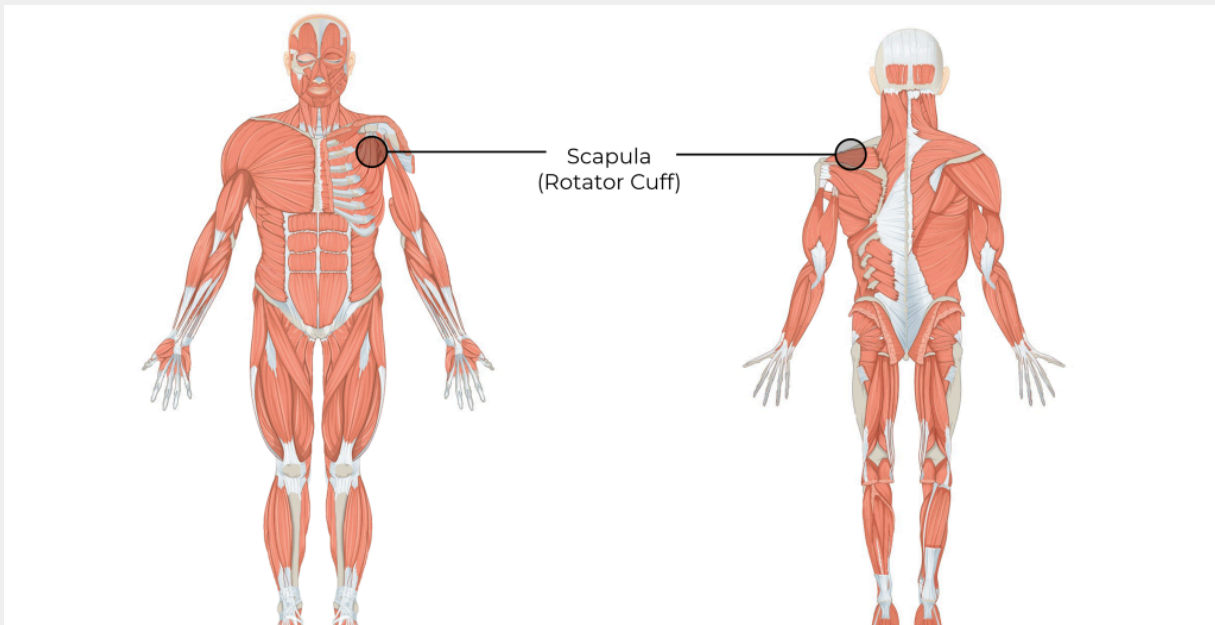


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Supraspinatus

Action: Abducts the shoulder

The supraspinatus is named after its location relative to the scapular spine.

- Supra-: meaning above
- Spinatus: referring to the scapular spine

Therefore, the supraspinatus can be found above the scapular spine.

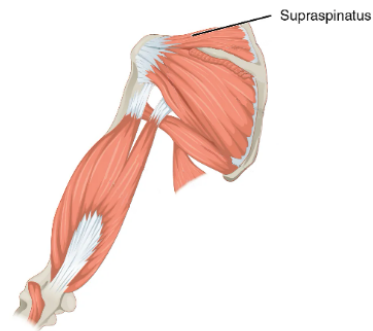


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Modified text labels

Infraspinatus

Action: *Externally rotates the shoulder*

The infraspinatus is named after its location relative to the scapular spine.

- Infra-: meaning below
- Spinatus: referring to the scapular spine

Therefore, the infraspinatus can be found below the scapular spine.

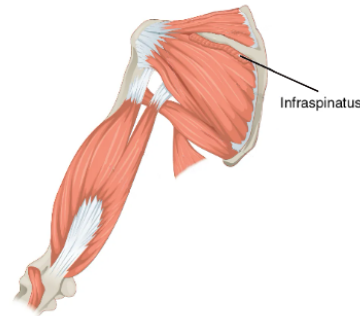


Image by OpenStax, CC BY 4.0
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Subscapularis

Action: *Internally rotates the shoulder*

Internally rotates the shoulder. The subscapularis is named after its location, 'under' or 'sub' the scapula.

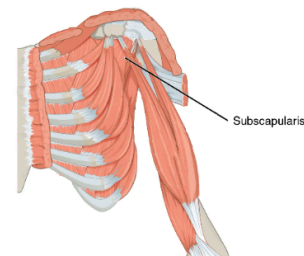


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5.7 MUSCLES OF THE THORAX AND ABDOMEN

← Pectoralis Major, External Obliques and Rectus Abdominis

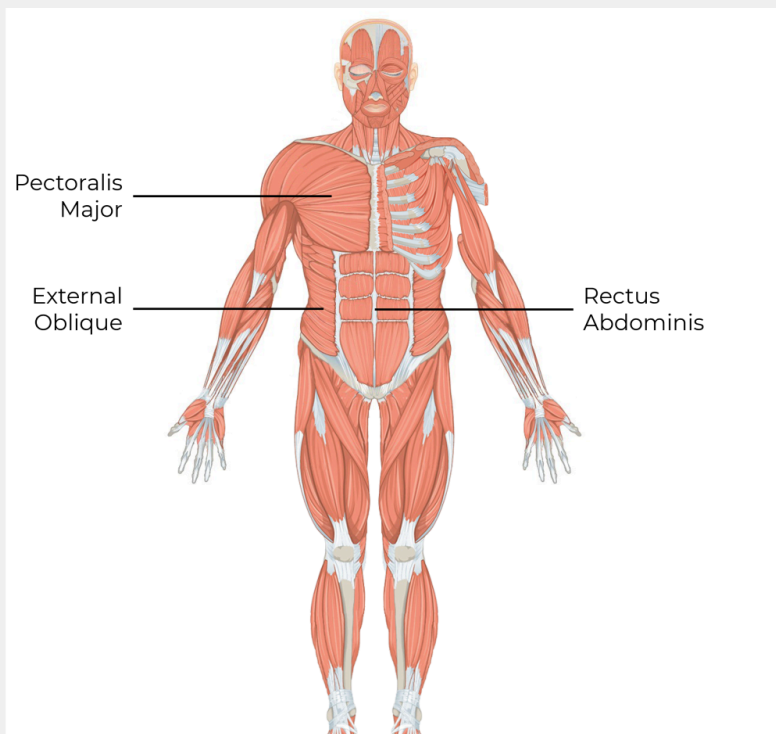


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Pectoralis Major

Action: *Internally rotates, adducts, and flexes the arm.*

This is the large chest muscle that is commonly referred to as the “pecs” short for pectoralis major.

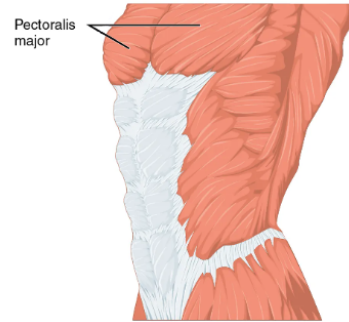


Image by OpenStax, CC BY 4.0
Modified text labels

External Oblique

Action: *Flexes and rotates the vertebral column.*

The external **oblique** is named for the direction of its muscle fibres as well as its anatomical position. The term ‘oblique’ is Latin for ‘slanting’ or ‘sideways’ and refers to muscle fibres that run diagonally. External refers to the fact that the muscle is superficial, external, or on the outside of the body.

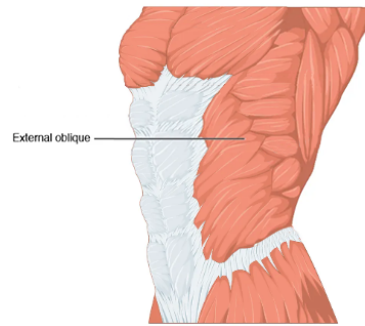


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Modified text labels

Rectus Abdominus

Action: *Flexes trunk*

The **rectus** abdominus (6-pack muscle) is named for the direction of its muscle fibres as well as its anatomical location. The term 'rectus' is Latin for 'straight' and refers to muscle fibres that run vertically (straight up and down). Abdominus refers to the muscle's location within the abdominal region.

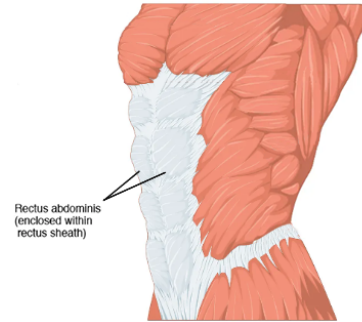


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Diaphragm

Diaphragm

Action: Aids in respiration (breathing) by decreasing or increasing pressure in the chest cavity to draw air into or force air out of the lungs, respectively.

The diaphragm is the umbrella shaped muscle located inferior to the lungs.

Video: “respiratory system-7 role of diaphragm in breathing” by Saurabh Jha [0:44] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

5.8 MUSCLES OF THE UPPER LIMB

↶ Deltoid, Biceps Brachii, and Triceps Brachii

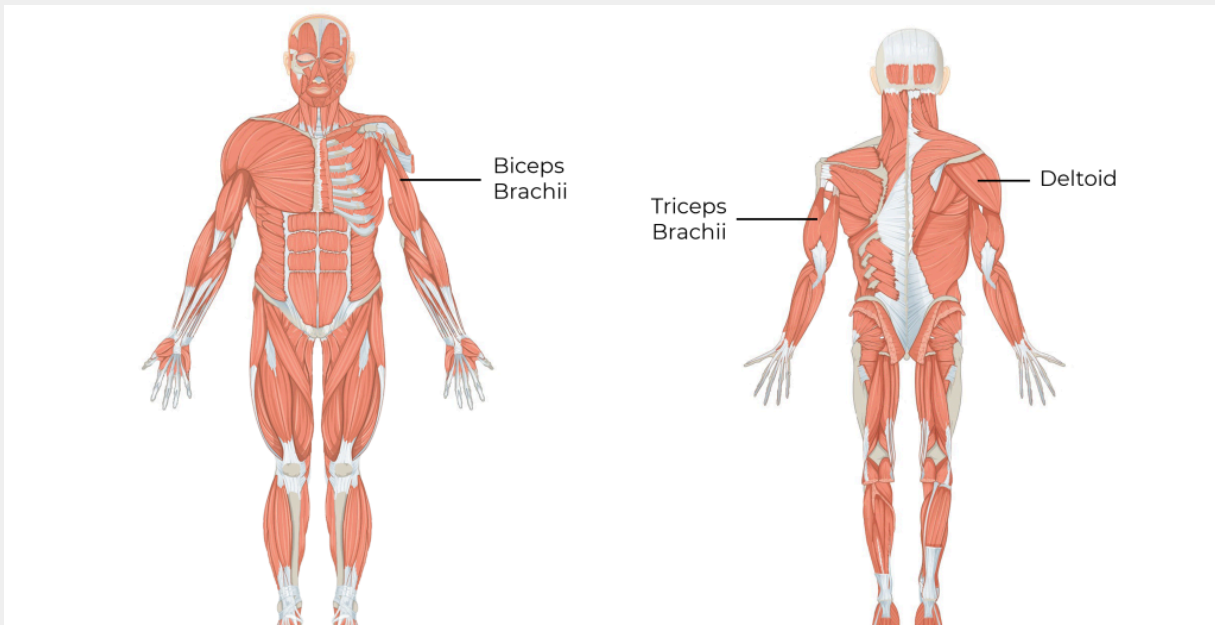


Image by OpenStax, CC BY 4.0. Modified text labels.

Deltoid

Action: Abduction, flexion, and extension of the shoulder

The deltoid is commonly referred to as the 'deltoids' and is the main superficial muscle of the shoulder. It is named after its shape which resembles the Greek letter delta (Δ).

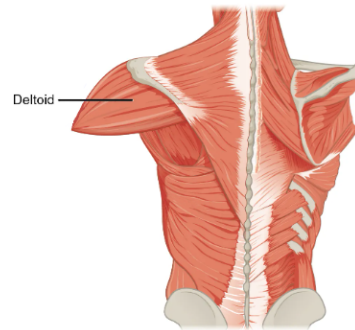


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Biceps Brachii

Action: Flexion of the elbow

The biceps brachii muscle is named for the number of heads the muscle contains as well as its location. The 'Bi-', meaning two, in biceps refers to the two heads the muscle contains. 'Brachii' refers to the muscle's location within the brachial (upper arm) region.

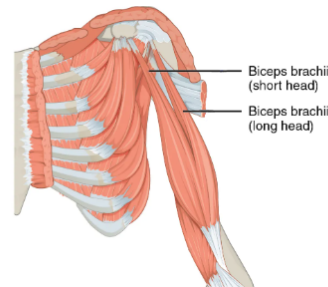


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Triceps Brachii

Action: Extension of the elbow

The triceps brachii muscle is named for the number of heads the muscle contains as well as its location. The 'Tri-', meaning three, in triceps refers to the three heads the muscle contains. 'Brachii' refers to the muscle's location within the brachial (upper arm) region.

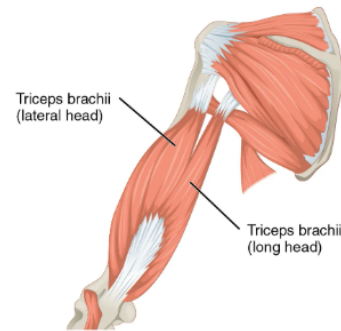


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5.9 MUSCLES OF THE BACK

← Latissimus Dorsi, Trapezius, and Erector Spinae Group

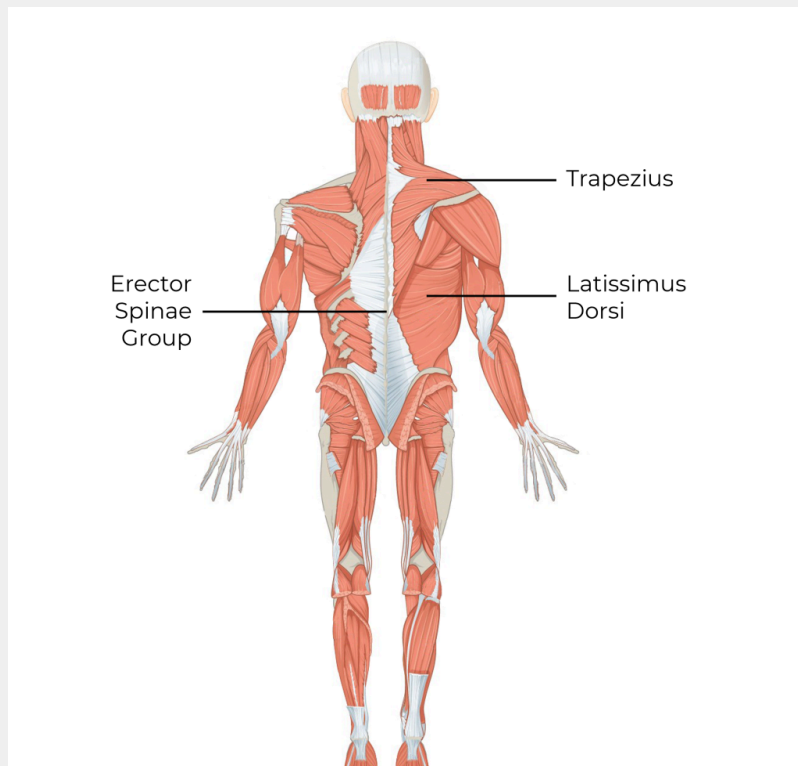


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Latissimus Dorsi

Action: *Adducts, extends, and internally rotates the arm*

The latissimus dorsi is often referred to as the 'lats' and is generally considered the largest muscle of the back. 'Latissimus' is Latin for 'broadest', referring to the muscle's large size, and 'dorsi' is Latin for 'back'... think dorsal fin being located on the back of a dolphin or shark.

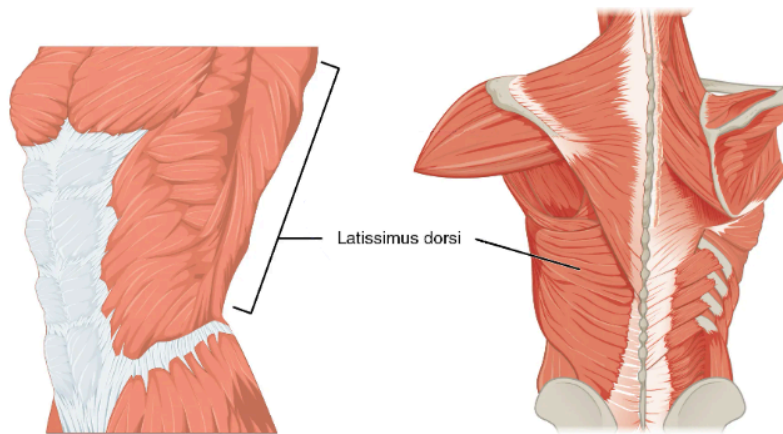


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Trapezius

Action: Elevation, retraction, and depression of the shoulders

The trapezius is often referred to as the ‘traps’ and is named after its trapezoid-like shape. It performs many actions due to the many directions of its muscle fibres.

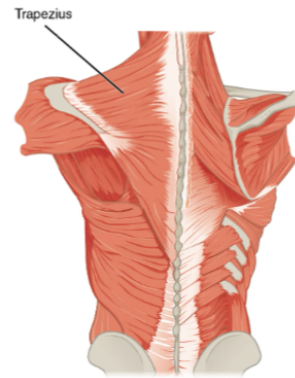


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Erector Spinae Group

Action: Extends and laterally flexes the spine

The erector spinae group consists of three muscles that work to keep the body upright.

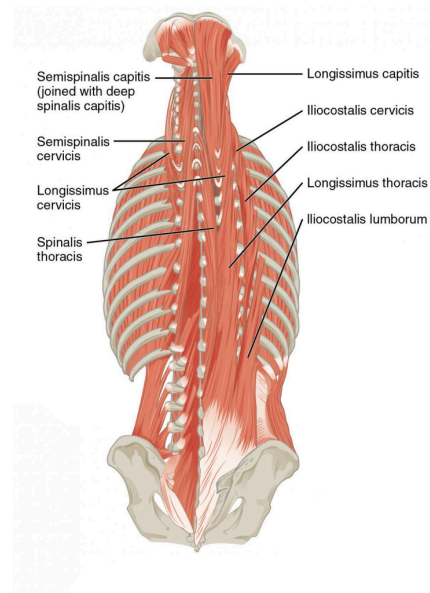


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5.10 MUSCLES OF THE HIP

← Hip Flexor Group, Gluteus Medius, and Gluteus Maximus

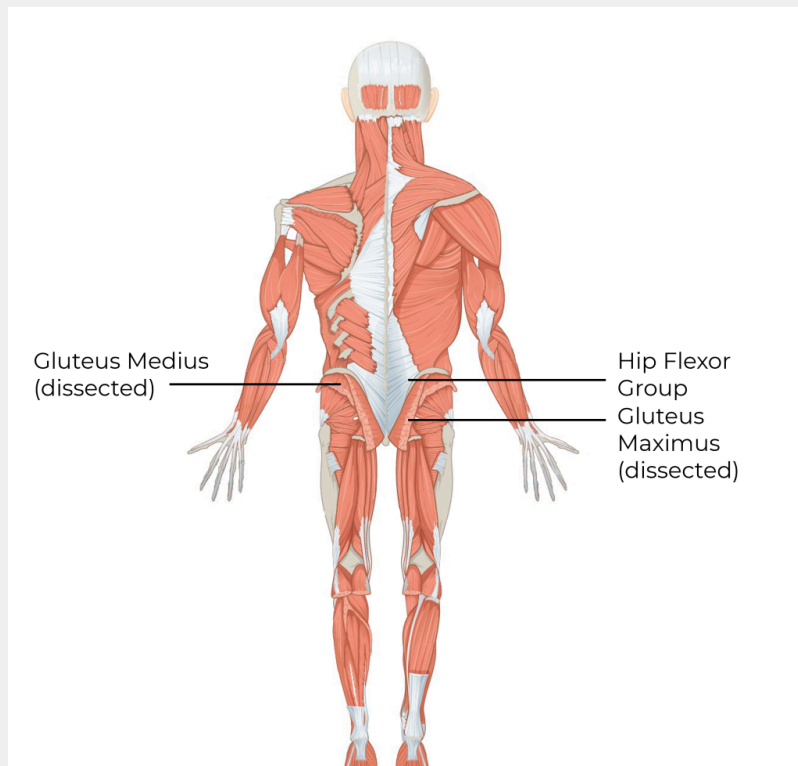


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Hip Flexor Group

Action: *Flexion of the hip.*

Made up of the iliacus and psoas major.

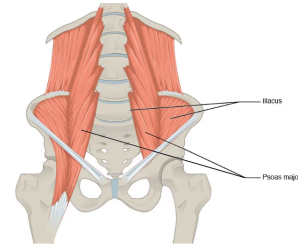


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Gluteus Maximus

Action: *Extension and external rotation of the hip.*

The gluteus maximus ('butt muscle') is named for its size and location. **Gluteus** refers to its location within the gluteal region, and **maximus** refers to it being not only the largest muscle in the gluteal region but also the largest muscle in the human body.

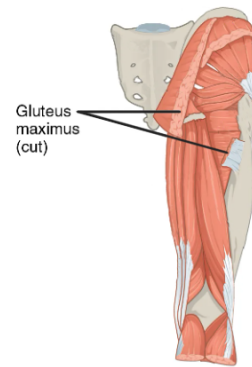


Image by OpenStax, CC BY 4.0
Modified text labels

Gluteus Medius

Action: Abduction of the hip.

The gluteus **medius** is named for its location. Gluteus refers to its location within the gluteal region, and medius (Latin for 'middle') refers to it being in the middle of the gluteus maximus and **minimus**.



Image by OpenStax, CC BY 4.0
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5.11 MUSCLES OF THE UPPER LEG

← Quadriceps Group, Hamstrings, and Adductor Group

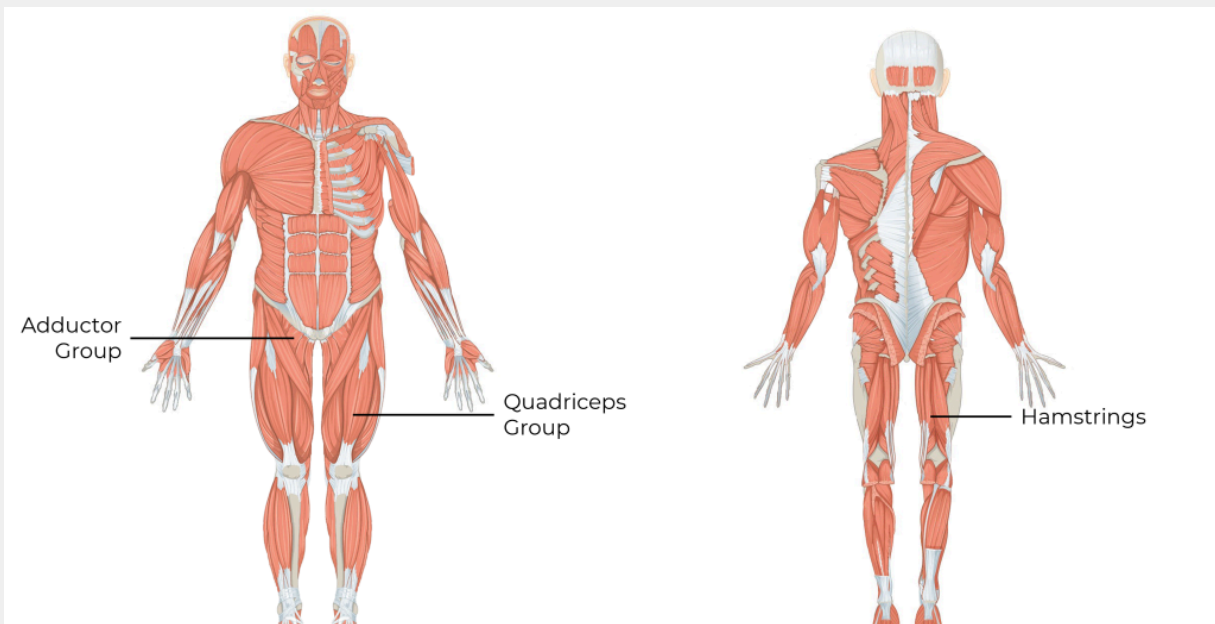


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Quadriceps Group

Action: *Knee extension and hip flexion*

Made up of the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. Also referred to as the “quads”.

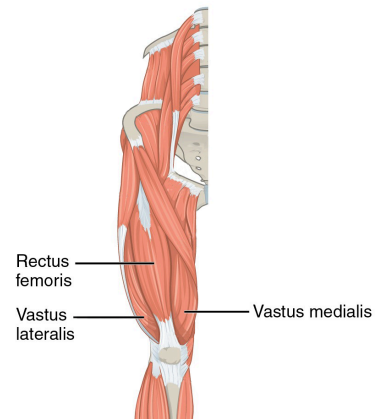


Image by OpenStax, CC BY 4.0
Modified text labels

Hamstrings

Action: *Knee flexion and hip extension*

Made up of the biceps femoris, semimembranosus, and semitendinosus. Also referred to as the “hammies”

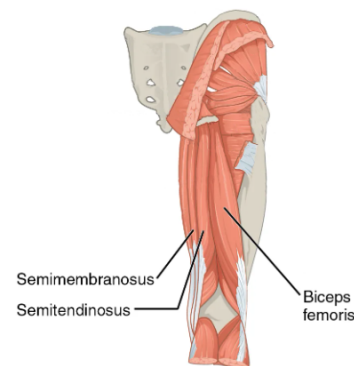


Image by OpenStax, CC BY 4.0
Modified text labels

Adductor Group

Action: Adduction of the hip

Made up of the adductor magnus, adductor longus, and adductor brevis.

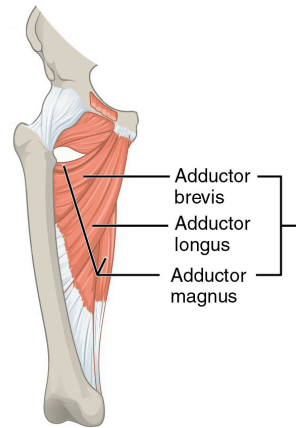


Image by OpenStax, CC BY 4.0
Modified text labels

5.12 MUSCLES OF THE LOWER LEG

Tibialis Anterior and Gastrocnemius

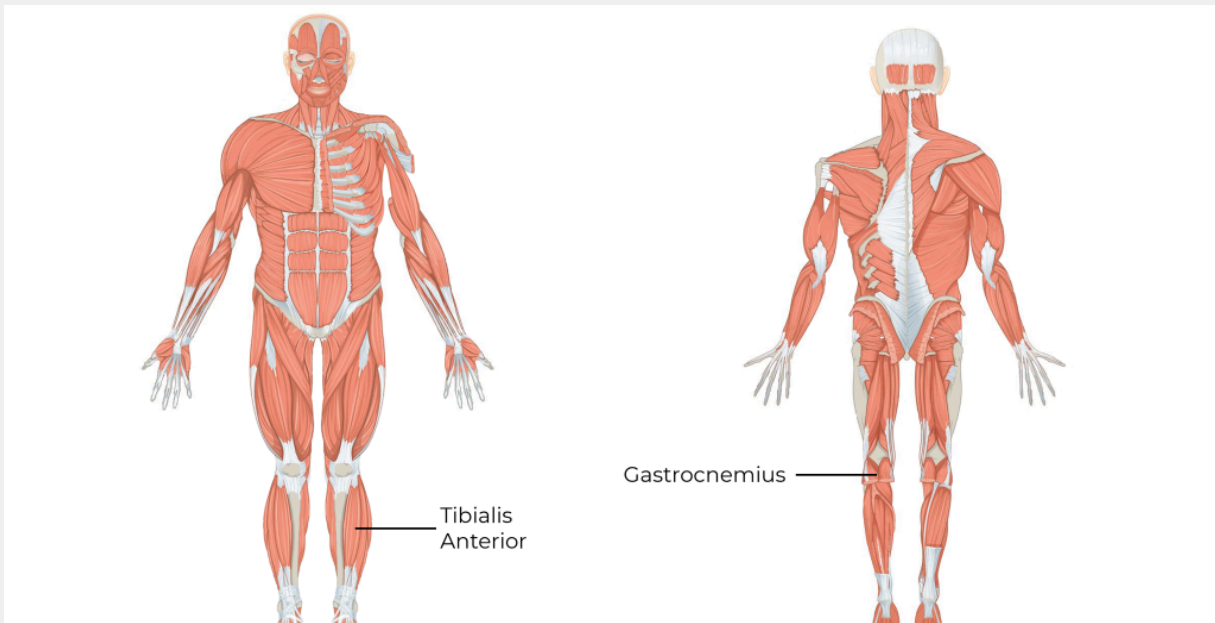


Image by OpenStax, CC BY 4.0. Modified text labels.

Tibialis Anterior

Action: Dorsiflexion

The tibialis anterior is named for its location and attachment on the anterior (front) portion of the tibia. It is the large muscle on the lateral aspect of your tibia.

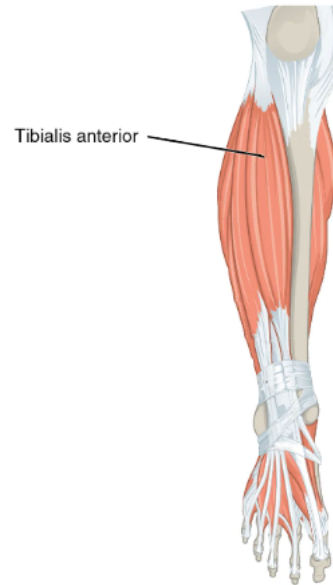


Image by OpenStax, CC BY 4.0
Modified text labels

Gastrocnemius

Action: Plantarflexion

The gastrocnemius is often referred to as the “calf” muscle.



Image by OpenStax, CC BY 4.0
Modified text labels

5.13 CHAPTER SUMMARY

Key Takeaways

- **Types and Functions of Muscle Tissue:** The human body contains three types of muscle tissue: smooth, cardiac, and skeletal. Smooth muscle controls involuntary actions within internal organs, cardiac muscle enables heart function, and skeletal muscle, which is under voluntary control, is primarily responsible for body movement and posture. Skeletal muscles are composed of fibres organized into fascicles, with microscopic units called sarcomeres being the functional contractile components.
- **Muscle Attachments and Movement Mechanics:** Muscles attach to bones either directly or via tendons and act at two key points: the origin (stationary) and insertion (movable). Muscles operate by pulling, not pushing, and can contract in three ways: concentric (shortening), eccentric (lengthening), and isometric (static).
- **Naming Conventions and Memorization Aids:** Many muscles are named based on Latin or Greek terms describing their shape, location, number of heads, or function. For example, the sternocleidomastoid references its attachment points, while rectus abdominis indicates its straight, abdominal location. These naming patterns help in memorizing anatomical structures effectively.
- **Regional Muscle Group Breakdown:** Key muscle groups make up various body regions, including the neck (e.g., sternocleidomastoid), thorax and abdomen (e.g., diaphragm, rectus abdominis), back (e.g., trapezius, latissimus dorsi), rotator cuff (e.g., supraspinatus), upper limb (e.g., biceps and triceps brachii), hip (e.g., gluteus maximus), upper leg (e.g., quadriceps, hamstrings), and lower leg (e.g., tibialis anterior, gastrocnemius). Each muscle is linked with its primary action.

- **Application Through Movement and Support:** Muscles play a vital role in supporting and enabling functional movements such as walking, lifting, breathing, and maintaining posture. The collaboration between agonists, antagonists, synergists, and stabilizers allows for controlled and efficient physical activity, making an understanding of muscular anatomy essential for fields like health, fitness, rehabilitation, and kinesiology.

OpenAI. (June 10th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into five key takeaways.

Key Terms

- **Agonist:** The primary muscle responsible for movement (e.g., biceps during elbow flexion)
- **Antagonist:** The muscle that opposes the action of the agonist and helps control movement
- **Cardiac Muscle:** Involuntary muscle found only in the heart; responsible for pumping blood; striated in appearance
- **Cleido-:** Refers to the clavicle
- **Concentric Contraction:** The muscle shortens as it contracts (e.g., lifting a dumbbell)
- **Eccentric Contraction:** The muscle lengthens while contracting (e.g., lowering a dumbbell)
- **Gluteus:** Refers to the buttocks/gluteal region
- **Infra-:** Below

- **Insertion:** The movable attachment site of a muscle, usually distal or lateral
- **Isometric Contraction:** The muscle contracts but does not change length (e.g., holding a weight in place)
- **Mastoid:** Refers to the mastoid process of the skull
- **Maximus/Medius/Minimus:** Latin for largest, middle, and smallest, respectively
- **Muscle Belly:** The largest, central part of a muscle; what you feel when touching your bicep
- **Muscle Fascicle:** A bundle of muscle fibres grouped together
- **Muscle Fibre:** A single muscle cell that makes up fascicles and forms the visible striations in muscle tissue
- **Myofibril:** Threadlike structures inside muscle fibres; composed of sarcomeres
- **Oblique:** Refers to diagonally oriented muscle fibres
- **Origin:** The fixed or less movable attachment site of a muscle, usually proximal or medial
- **Rectus:** Latin for “straight,” indicating vertical alignment of muscle fiber
- **Sarcomere:** The smallest functional unit of muscle contraction within a myofibril
- **Skeletal Muscle:** Voluntary muscle attached to bones; responsible for body movement; striated and under conscious control
- **Smooth Muscle:** Involuntary muscle found around internal organs (e.g., blood vessels, digestive tract); contracts slowly and is not consciously controlled
- **Stabilizer:** A muscle that supports or stabilizes a joint during movement, preventing unwanted motion
- **Sterno-:** Refers to the sternum
- **Sub-:** Under or beneath
- **Supra-:** Above
- **Synergist:** A muscle that assists the agonist in performing a movement

OpenAI. (June 10th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

5.14 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. Which of the following muscle types is under voluntary control?

- Smooth muscle
- Cardiac muscle
- Skeletal muscle
- Visceral muscle

2. What is the correct pairing for muscle attachment terms?

- Origin – more movable; Insertion – fixed
- Origin – distal; Insertion – proximal
- Origin – fixed; Insertion – movable
- Origin – external; Insertion – internal

3. What action occurs during an eccentric muscle contraction?

- The muscle shortens
- The muscle lengthens
- The muscle remains the same length
- The muscle twists

4. Which of the following muscles is part of the rotator cuff?

- Deltoid
- Gluteus Maximus

- Supraspinatus
- Rectus Abdominis

5. Which action is the quadriceps muscle group primarily responsible for?

- Elbow flexion
- Hip abduction
- Knee extension
- Shoulder rotation

6. What does the term “rectus” indicate in a muscle’s name?

- Diagonal fibre direction
- Located near the spine
- Straight fibre direction
- Circular shape

7. Which muscle is primarily responsible for plantarflexion?

- Tibialis Anterior
- Gastrocnemius
- Deltoid
- Biceps Brachii

Correct Answers:

1. Skeletal muscle
 2. Origin – fixed; Insertion – movable
 3. The muscle lengthens
 4. Supraspinatus
 5. Knee extension
 6. Straight fibre direction
 7. Gastrocnemius
-

OpenAI. (June 11th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 6: ENERGY SYSTEMS, FUELING, AND TRAINING PRINCIPLES

Chapter Overview

- 6.0 Learning Objectives
- 6.1 Adenosine Triphosphate (ATP)
- 6.2 Anaerobic Metabolism: ATP-CP
- 6.3 Anaerobic Metabolism: Glycolysis
- 6.4 Aerobic Metabolism: Cellular Respiration
- 6.5 Anaerobic vs Aerobic Metabolism
- 6.6 Energy Systems vs Muscle Make-up
- 6.7 Training Principles
- 6.8 Chapter Summary
- 6.9 Knowledge Check

6.0 LEARNING OBJECTIVES

Learning Objectives

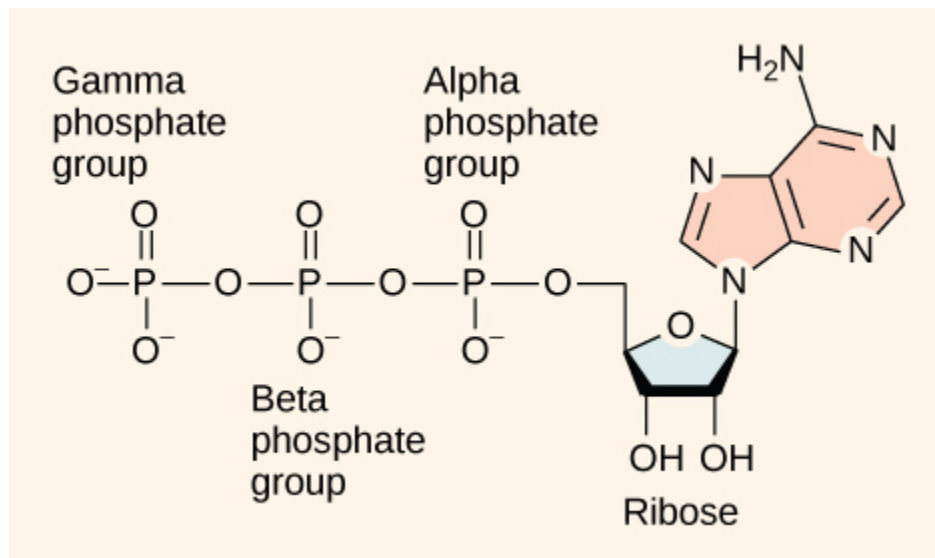
At the end of this chapter, you will be able to:

- Define ATP and its role in fueling physical activity.
- Differentiate between anaerobic and aerobic metabolic pathways.
- Recognize which metabolic pathways primarily fuel specific types of activity.
- Identify and differentiate between training principles.
- Recognize how to apply training principles.

6.1 ADENOSINE TRIPHOSPHATE (ATP)

The Common Energy Molecule

To perform daily tasks and participate in physical activity, the body requires energy that we get from consuming food. Once consumed, food is broken down by our digestive system and converted into a universal form of “free energy” that can be used for muscle contraction and other bodily functions we need to survive. The final form this “free energy” takes is a molecule called **Adenosine Triphosphate (ATP)**.



“ATP Energy Molecule” by Amanda Shelton, CC BY 4.0

Since the body requires ATP in such high demand, the body uses multiple methods to synthesize it. Here we will discuss two classes of energy systems that help to produce ATP: the Anaerobic System and the Aerobic System.

“ATP in Living Systems” from Introduction to Exercise Science for Fitness Professionals by Amanda Shelton is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

6.2 ANAEROBIC METABOLISM: ATP-CP PATHWAY

The Anaerobic System

The **Anaerobic System** is an energy system which acts relatively quickly in resynthesizing ATP. While the system is quick to respond to a sudden demand for ATP, the capacity of the system to sustain ATP production is limited. This means that this anaerobic system is only able to provide adequate levels of ATP for a short period of time or short-lived bouts of physical activity, such as weightlifting. One reason this system only provides enough ATP for intense, but short periods, is that it doesn't utilize oxygen. Anaerobic, by definition, actually refers to "living, active, occurring, or existing in the absence of free oxygen" (Merriam-Webster, n.d.). Within the anaerobic system, two different pathways work to resynthesize ATP to meet the body's demands: The ATP-CP and Glycolysis pathways.



Collage of athletes performing short-duration, high-intensity activities powered by the ATP-CP pathway. Includes a woman preparing for a shot put throw, two sprinters at the starting line of a 100m dash, and a man lifting a barbell. These anaerobic actions rely on rapid ATP resynthesis without oxygen. Image (left): "Woman Athlete" by Boom, Image (top right) by Andrea Piacquadio, and Image (bottom right) by Victor Freitas, Pexels License

The ATP-CP Pathway

The **ATP–CP pathway** (also known as the Phosphagen system or the ATP-PCr system) is the least complex of the three major energy-producing systems because it involves a singular exchange between molecules, which results in the release of energy. The ATP-CP system uses Creatine Phosphate (CP) to convert Adenosine Diphosphate (ADP) into ATP. It does so by removing one phosphate molecule (dephosphorylation) from creatine phosphate and, through creatine kinase, combines it with ADP (which has two phosphate molecules), resulting in ATP (which has three phosphate molecules). The process of adding a phosphate molecule to ADP dephosphorylates ADP into ATP.

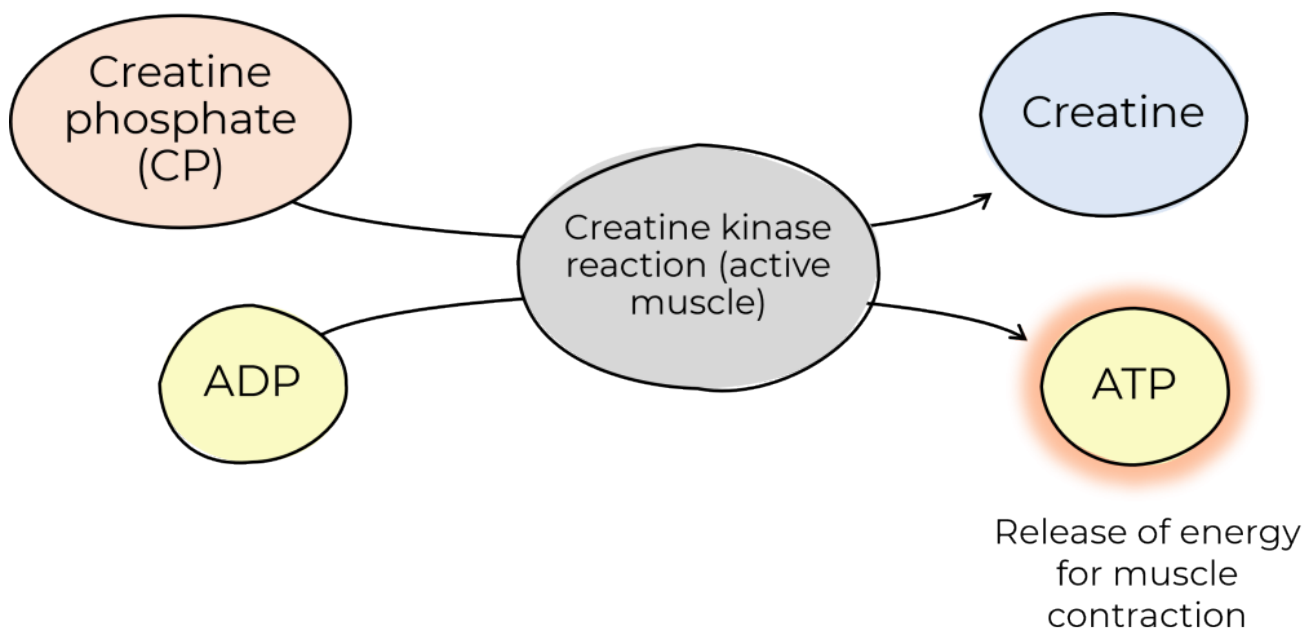


Diagram of the ATP-CP pathway showing creatine phosphate (CP) donating a phosphate to ADP through the creatine kinase reaction in active muscle, forming ATP and creatine. This fast-acting energy system provides immediate energy for short bursts of activity. “ATP-CP System” by saudette, CC BY-NA-SA 4.0

In general, the less complex the system, the fewer chemical reactions must take place so ATP can be produced faster. However, these quick reactions are not the most energy efficient, so fewer ATP will be produced per unit of fuel. Since this system is the least complex, it is also the fastest and most immediate, but provides the least amount of ATP. Once the body requires energy, it will once again modify that ATP molecule by breaking off one of its three phosphate molecules (dephosphorylation) and the cycle begins again.

ATP-CP Pathway Summary

- Yields enough ATP for approximately 10 to 15 seconds of intense activity
- Relies on creatine phosphate (CP), which is readily accessible in muscle tissue
- Muscles do not have a large supply of CP, resulting in depleted stores quickly (requires 2 to 5 minutes to resynthesize)

Fitness Fact



“Energizer” by Undraw,
Undraw License

While supplements may not be required in every diet, some individuals may benefit from consuming them if their diet isn't adequate in meeting the body's demands. CP, from the ATP-CP pathway, is created when the creatine you eat or synthesize is transported to your muscle tissue and phosphorylated in the muscle. This is how your muscles store phosphate that can be used to rapidly dephosphorylate ADP to ATP. CP is sometimes referred to as phosphocreatine (PCr).

“8.3 Phosphagen System (ATP-CP System)” from Nutrition and Physical Fitness by Angela Harter Alger is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted. Modifications: rephrased.

6.3 ANAEROBIC METABOLISM: GLYCOLYSIS

The Glycolysis Pathway (Anaerobic)

Glycolysis is another metabolic pathway that generates ATP anaerobically by using carbohydrate in either the form of glucose or glycogen.



Collage of athletes engaging in sports that rely on the glycolysis pathway for anaerobic energy production. Includes a football player holding a ball, a woman jogging, and two hockey players on the ice. These sports involve short bursts of high-intensity activity supported by carbohydrate breakdown without oxygen.

Image (top left): “Football player” by Pixabay, Image (bottom left): “Girl running” by Nathan Cowley, Image (right): “Hockey players” by Lynda Sanchez, Pexels License

Glycolysis begins with the six-carbon, ring-shaped structure of a single glucose molecule and ends with two molecules of a three-carbon sugar called pyruvate. Glycolysis consists of two distinct phases. In the first part of the glycolysis pathway (A), two ATPs are required so that the six-carbon sugar molecule can be split evenly into two three-carbon pyruvate molecules. In the second part of glycolysis (B), four ATPs and two NADHs are produced. After subtracting the two ATP required upfront, the net yield of glycolysis when starting with glucose is 2 ATP, 2 NADH, and two pyruvate molecules. Muscle glycogen enters glycolysis partway through the first phase of glycolysis, and only one ATP is required upfront. This means that when starting with

muscle glycogen, the net yield of glycolysis is 3 ATP, 2 NADH, and two pyruvate. This is why exercising muscles preferentially use muscle glycogen instead of blood glucose when glycogen is available.

Try This!

Click on the icons below to learn more about each step in glycolysis.

Image Description

- Two Pyruvate: Two pyruvates move to the next stage of cellular respiration.
- Glucose Molecule: The 6-carbon glucose molecule is split into 2 separate 3-carbon pyruvate molecules.
- Net gain of 2 ATP: Produces 4 ATP but uses 2 ATP, resulting in a net gain of 2 ATP released into the cell for energy use.
- 2 NADH: Produces 2 NADH that travel to the mitochondria, carrying high-energy electrons to the ETC.

Glycolysis Summary

- Yields enough ATP for approximately 1 to 3 minutes of intense activity.
- Relies on the supply of glucose, which can be present in the blood or as glycogen in muscle.
- Pathway creates a by-product called lactic acid.
- Pathway requires anywhere from several minutes to 2 hours of rest to fully recover, depending on how much lactic acid is present.

Fitness Fact



“Running wild” by
Undraw, Undraw
License

Lactate or **lactic acid** is a byproduct of glycolysis when the demand for glucose outweighs the oxygen available to help break it down. It is a common myth that the accumulation of lactate in the muscle contributes to the ‘burning’ or sore feeling many of us experience during or shortly after we exercise. While lactic acid does build up during strenuous activity, it’s the dissociation of lactate that leads to acidity of muscle tissue through the accumulation of positively charged hydrogen ions (H^+).

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6.4 AEROBIC METABOLISM: CELLULAR RESPIRATION

The Aerobic System

So far, we have discussed the two most immediate anaerobic energy systems: the ATP–CP system and glycolysis. Although these systems are able to provide ATP very quickly, their major limitation is their relatively short duration of action. In the **Aerobic System**, carbohydrate, protein, and fat can be used to generate ATP. As demonstrated by the diagrams below, this system is significantly more complex than anaerobic metabolism.



Collage of athletes participating in endurance-based sports that rely on the aerobic energy system. Includes long-distance runners on a trail, competitive cyclists in a race, and soccer players in a game. These activities require sustained ATP production using oxygen over extended periods. Image (top left) “Two men running” by RUN 4 FFWPU, Image (bottom left) “Cycling” by Pixabay, Image (right) “Three men playing soccer” by Pixabay, Pexels License

The Krebs Cycle & The Electron Transport Chain (ETC)

Cellular respiration, which includes the **Krebs cycle** and the **Electron Transport Chain (ETC)**,

collectively referred to as aerobic metabolism, can provide ATP on a virtually limitless basis as long as fuel (carbohydrate, fat, or protein) and oxygen are available. While this text will not dive deep into specific pathways of cellular respiration, it will examine key differences between its method of ATP production in comparison to Anaerobic metabolism.

Try This!

Click on the icons below to learn more about each step in the Krebs cycle and the ETC.

Image Description

Citric Acid Cycle:

- 4 Carbon Dioxide: Each Acetyl CoA enters the cycle, releasing 2 CO². Four carbon dioxide diffuse out of the cell.
- Two ATP: Two ATP (1 ATP per pyruvate, two pyruvates total) are released into the cell for energy use.
- Oxaloacetate: Acetyl CoA drops the acetic acid off onto oxaloacetate. These 2 carbons get released as 2 CO² and oxaloacetate remains in the cycle to be reused. This repeats for the 2nd acetyl coA, producing a total of 4 CO²).
- 6 NADH and 2 FADH²: Produces 6 NADH, 2 FADH² (3 NADH and 1 FADH² per pyruvate, two pyruvates total), that bring high-energy electrons to the ETC.

Image Description

Electron Transport Chain (ETC)

- NADH and FADH²: NADH and FADH² from previous stages drop high-energy electrons off at ETC, becoming NAD⁺ and FAD for reuse.
- ATP: Each NADH yields 3 ATP (10 × 3 = 30 ATP), each FADH² yields 2 ATP (2 × 2 = 4 ATP), total of 34 ATP produced through redox reactions
- H₂O: O₂ serves as the final electron acceptor in the ETC, facilitating ATP production and generating water as a waste product.

Collectively, cellular respiration produces enough ATP for several hours of moderately intense physical activity by relying on a supply of glucose (carbohydrate), protein, fat, and, of course, oxygen. The amount of ATP produced greatly exceeds that of anaerobic metabolic pathways, but becomes impaired when oxygen is no longer present or is not present in sufficient quantities. In this case, cellular respiration would cease, and glycolysis would begin.

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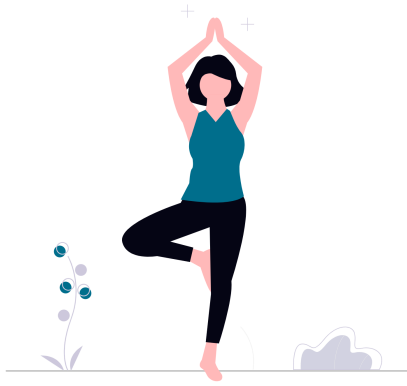
6.5 ANAEROBIC VS AEROBIC METABOLISM

The chart below compares anaerobic and aerobic metabolic pathways. As shown, each system plays a distinct role depending on the duration of activity and the resources available. Generally speaking, the anaerobic pathways, ATP-CP and Glycolysis, supply the body with ATP and recovery relatively quickly but only provide us enough ATP for short bouts of strenuous activity. Aerobic pathways, however, act differently by providing long-term energy and recovery on an ongoing basis, reducing the system’s recovery duration to nearly zero, all while supplying the body with more efficient ATP production.

Comparing Anaerobic & Aerobic Pathways

Anaerobic			
Energy Source	Energy Duration	System Recovery Duration	Net ATP Gain
ATP-CP Pathway	10 to 5 seconds	2 to 5 minutes	1 ATP per CP molecule
Glycolysis	1 to 3 minutes	Several minutes to 2 hours	2 ATP per glucose molecule
Aerobic			
Energy Source	Energy Duration	System Recovery Duration	Net ATP Gain
Krebs Cycle	2 minutes – sustained	Ongoing, no full “shutdown”	2 ATP per glucose molecule
ETC	Sustained	Ongoing, oxygen-dependent	32 to 34 ATP per glucose molecule

Fitness Fact



“Yoga” by Undraw, Undraw License

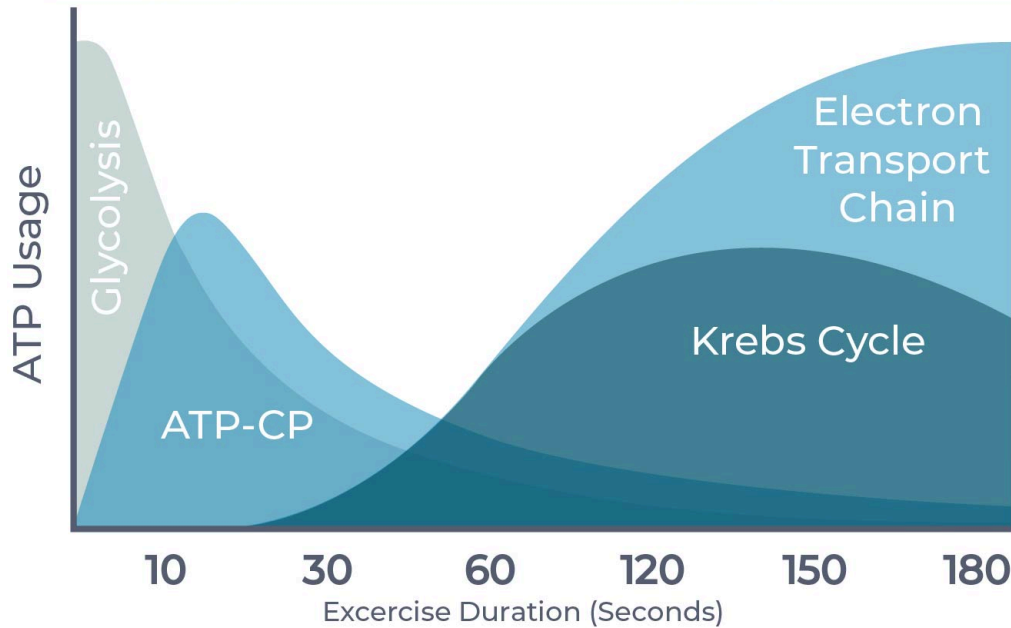
What Energy System am I using?

It is a common misconception that the body only utilizes one energy system at a given time. While you may be engaging in physical activity that can easily be associated with a specific energy system based on the demand it puts on the body, the body is complex and relies on multiple systems in order to maintain ATP levels. For example, when you are running and start to get tired, it is easy to believe that the body “switches” from cellular respiration to glycolysis; however, this is simply untrue. In reality, both aerobic and anaerobic systems are working to meet physical demands for energy.

Energy Systems in Action During Physical Activity

The graph below shows what energy systems are predominantly active during exercise over time. This includes ATP-CP pathway, glycolysis, the Krebs cycle and the ETC.

Energy System In Action During Physical Activity



Graph showing ATP usage by different energy systems over 180 seconds of exercise. The ATP-CP system peaks early around 10 seconds, glycolysis follows and declines after 60 seconds, while the Krebs cycle and electron transport chain gradually increase and dominate after 90 seconds, reflecting a shift from anaerobic to aerobic metabolism. See source below. Modified by Koen Liddiard

Energy System Contribution During Exercise Graph: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: "I need a graph type image that shows what energy systems are prodominantly active during exercise duration over time. I need it to include the ATP-CP pathway, glycolysis, the Krebs cycle and the Electron transport chain."

6.6 ENERGY SYSTEMS VS MUSCLE MAKE UP

Consider that an individual's muscle make-up can be helpful in understanding how energy systems supply our body with fuel. While muscles and muscle fibre types are discussed in Chapter 5, understanding how muscles function can help indicate the types of energy systems our body will favour.

Movement in Action

Let's take a look at two well-known Canadian athletes. On the left is Rory Linkletter, a Canadian Marathon runner who competed in the Paris 2024 Olympics and on the right is Andre De Grasse, a Canadian sprinter. Both are clearly physically fit to compete in their respective sport at a high-performance level. However, each athlete's muscle makeup is very different from the other.



Side-by-side images of two Canadian Olympic athletes: Rory Linkletter, a marathon runner, on the left during a long-distance road race; and Andre De Grasse, a sprinter, on the right, celebrating with a baton after a relay. The image highlights differences in athletic performance and muscle composition between endurance and sprint athletes. Left photo: Rory Linkletter, by 4300streetcar, CC BY 4.0, Right photo: Andre De Grasse, by Erik van Leeuwen, GNU License

Muscle fibre types can exist as either type 1 or type 2/2b.

Type 1 Muscle Fibres (Rory Linkletter)	Type 2/2b Muscle Fibres (Andre De Grasse)
• Known as slow-twitch fibres and favour aerobic activity. • Fatigue slowly and are dense in capillaries and mitochondria, and therefore have a high blood supply. • As a result, type 1 muscle fibres are red in colour.	• Known as fast-twitch fibres and favour anaerobic activity. • Fatigue quickly and house a lower number of capillaries and mitochondria, and therefore a low blood supply. • As a result, type 2 muscle fibres are pale in colour.

So, how does this relate to our athletes above?

Well, the average individual will not often demonstrate the same phenomenon as these elite athletes can. Because both athletes are highly trained in their sport, their bodies have adapted to their advantage. Over time, this has caused their bodies to produce more of one muscle fibre type over another. Meaning, Rory Linkletter, who prominently engages in long-distance running, will have more type 1 or slow-twitch fibres. This is because marathon running, or long-distance running, is an aerobic activity that uses cellular respiration for the majority of its ATP demands. However, an Olympic sprinter, like Andre de Grasse, who engages in short but very strenuous bouts of activity, will have more type 2 or fast-twitch fibres. This is because sprinting is an anaerobic activity that uses both the ATP-CP pathway and Glycolysis for ATP production.

Can you alter your own muscle fibre makeup if you are not an elite athlete?

Absolutely, you can. Although everybody is born different, some individuals may be born with more type 1 over type 2, the opposite, or a complete 50 to 50 split of each type. If trained consistently, your body can adapt to the change in demands you place on it.

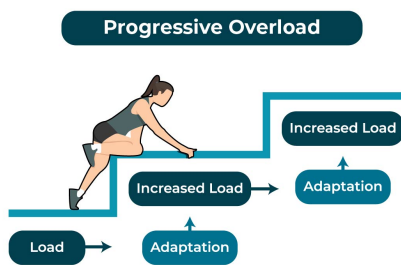
6.7 TRAINING PRINCIPLES

Previously noted in Chapter 2, the FITT principle offers a useful foundation for planning exercise programming. However, to achieve continued progress, it's important to apply additional training principles such as the following:

- Progressive overload
- Specificity
- Reversibility
- Diminishing returns
- Individuality

Progressive Overload

“The idea that in order to see progress, you must continue to challenge yourself by increasing the frequency, duration, or intensity of your training.”



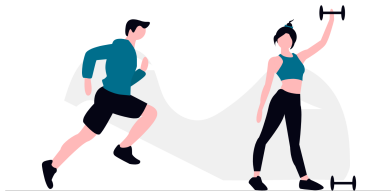
“Progressive Overload” by Koen Liddiard, CC BY-NC-SA 4.0

Imagine you want to gain lower-body strength, so you decide to start squatting with a 10 kg kettlebell. At first, it feels challenging, but after a few weeks, the same weight starts to feel easier. To keep improving, you have decided to increase your weight to 15 kg. Once again, after a few weeks, the 15 kg weight starts to feel easier. This principle is known as **progressive overload**. It refers to the gradual increase of stress placed on the body during training. Stress can be increased

through a number of methods, including but not limited to increased weight, repetitions, or sets of exercise. As the body adapts to these challenges, continued improvement requires the introduction of new demands. Without this progression, physical development will eventually plateau.

Specificity

“The idea that you need to do specific exercises to improve a specific aspect of your fitness.”



“Athletes training” by Undraw,
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The principle of **specificity** describes how the body adapts to the type of training it performs. To improve the performance of a particular activity, training must mimic the demands of that activity. This means that the training should closely reflect the movements, muscles, and energy systems involved. For example, someone aiming to improve their running ability should focus primarily on

running-based workouts. This principle does not neglect that training should include a variety of exercises and avoid overtraining. However, it does support the idea that if you are trying to gain muscular strength, for instance, engaging in strength training will benefit you more than other activities.

Reversibility

“The idea that if you stop exercising (or stop a particular activity), you lose the effects of training.”



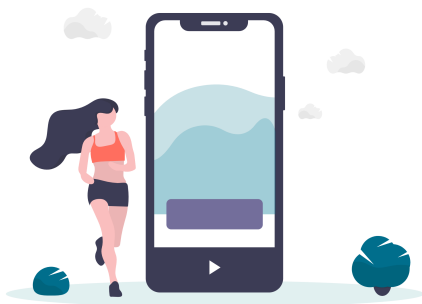
Sometimes referred to as detraining, **reversibility** refers to the decline in physical fitness or ability that occurs when training is reduced or stopped altogether. Reversibility can occur because of injury or overuse, forcing an individual to scale back or take a leave from training; a lack of motivation due to a change in priorities or interest; or other commitments impeding the current training regimen or schedule.

For instance, most professional athletes operate on an “on-season” and “off-season” schedule where the on-season is spent adhering to a strict training regimen, and the off-season is spent resting, refreshing, or potentially maintaining a lower level of physical fitness. During the off-season, such athletes would experience reversibility in that some of their training benefits are lost until they return to their on-season regimen.

“Injured” by Undraw, Undraw License

Diminishing Returns

“The idea that an athlete will eventually reach a plateau in performance where progress in training begins to level off and further improvements become harder to achieve.”



“Fitness tracker” by Undraw, Undraw License

When an individual first starts working out or starts working in an area or skill they haven't prioritized before, they often see noticeable improvements in a relatively short period of time. This may present as more strength, better endurance, weight loss or gain, or visible changes in muscle tone. Over time, improvements will become smaller and harder to achieve.

This is the principle of **diminishing returns** that describes how an individual new to an activity or exercise will see substantial improvements during the first few weeks or months of participation. However, once an individual becomes more trained, improvements will be smaller and harder to achieve. This is because humans cannot train and expect indefinite improvement- eventually, we will reach a performance plateau. For example, a beginner weightlifter may be able to increase their weight by 2 to 3 kg every 2 weeks due to noticeable changes in strength. However, once they become more trained, they may only be able to increase their weight by 0.5 to 1 kg every 4 weeks because they are working closer to their performance plateau.

Individuality



“Hiking” by Undraw, Undraw License

“The idea that each person is unique and there is no one-size-fits-all best way to train.”

All individuals are unique in their exercise programming needs. Personal, environmental, and behavioural factors should be considered and assessed when planning to engage in a physical fitness training regimen (American College of Sports Medicine, 2013). Consider an individual attempting to become more physically fit, engaging in an activity that they do not enjoy, that is not easily accessible to them and does not align with their home life as a parent of young children. Do you think this program is going to work well for them? Absolutely not.

Physical activity, while something everyone should participate in every day, will not look the same for every individual, and there is nothing wrong with that. If you do not like to run, a weekly swimming group might be a better fit than joining a local running club. If you find yourself bored walking on a treadmill, make use of hiking trails or paths in your area. And if you do not want to or cannot commit to deliberate exercise in a gym, class or on your own, find ways to incorporate physical activity into your daily life. For example, biking to work instead of driving; playing with your kids at the park instead of watching them from a bench; or completing yard work

yourself rather than hiring help. Physical activity does not have to be boring or part of the day you dread. It can be something you enjoy and look forward to every day, whether you enjoy the endorphins you get from physically moving, you appreciate the company you have while working out, or use physical activity as downtime and listen to an audiobook.

Bust a Myth!

Contrary to a common belief, physical training is not something only elite athletes can engage in. Any individual, regardless of age, ability, or previous experience, can adapt the basic principles of training into an exercise program that suits their needs and desires. Where possible, work with a qualified trainer or coach to create an appropriate program that considers the following factors:

- Pre-fitness training level
- Age
- Gender
- Previous injuries or susceptibility to injury
- Medical conditions or ailments
- Specific requirements within a sport (if applicable)
- Individual desire or need



“Woman doing exercise” by Pixabay,
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“1.7 Designing a Structured Exercise Program” from Nutrition and Physical Fitness by Angela Harter Alger is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

“1.8 Training Principles” from A Guide to Physical Activity by Eydie Kramer is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

6.8 CHAPTER SUMMARY

Key Takeaways

- **ATP is the Body's Universal Energy Currency:** All physical activity relies on adenosine triphosphate (ATP), a molecule generated from food that fuels muscle contraction. Because the body uses large amounts of ATP, it synthesizes it through multiple energy systems.
- **ATP-CP system (Anaerobic)** provides energy for up to 15 seconds of high-intensity effort using creatine phosphate.
- **Glycolysis (Anaerobic)** supports short bursts (1 to 3 minutes) using glucose or glycogen without oxygen, producing lactic acid.
- **Cellular Respiration (Aerobic)** includes the Krebs Cycle, the ETC, and uses oxygen and various fuels (carbs, fats, proteins) to supply sustained energy for prolonged activities.
- **Muscle Fibre Types Influence Energy Use:** Type 1 (slow-twitch) fibres are optimized for aerobic endurance, while Type 2/2b (fast-twitch) fibres support anaerobic, explosive activities. Training can shift muscle fibre balance based on the energy system predominantly used.
 - Type 1 (slow-twitch) fibres are optimized for aerobic endurance, and they are more red in colour because they have a greater blood supply for oxygen transport.
 - Type 2/2b (fast-twitch) fibres are optimized for aerobic, short-lived physical activity, and they are paler than type 1 fibres because they do not utilize oxygen in the production of ATP.

- **Training Principles Guide Effective Exercise:** Concepts like progressive overload, specificity, reversibility, diminishing returns, and individuality help tailor fitness programs for continued improvement and sustainability.
- **Energy Systems Work Together, Not Separately:** The body does not switch from one energy system to another but uses all systems in varying degrees depending on activity type, intensity, and duration to maintain adequate ATP levels.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into key takeaways.

Key Terms

- **Adenosine Triphosphate (ATP):** A molecule that stores and transfers energy within cells, acting as the primary energy currency for muscle contraction and other bodily functions.
- **Anaerobic System:** Energy production that occurs without the use of oxygen; supports short-duration, high-intensity physical activity.
- **Aerobic System:** Energy production using oxygen to convert carbohydrates, fats, and proteins into ATP; supports long-duration, moderate-intensity activity.
- **ATP-CP Pathway (Anaerobic):** An anaerobic system that supplies ATP to working muscles using creatine phosphate for 10 to 15 seconds of intense activity.
- **Cellular Respiration (Aerobic):** A complex aerobic process involving the Krebs Cycle and Electron Transport Chain to produce ATP from glucose, fat, or protein.

- **Electron Transport Chain (ETC):** The final stage of aerobic respiration that produces the majority of ATP in cells through oxidative phosphorylation.
- **Krebs Cycle:** A sequence of chemical reactions in aerobic metabolism that generates energy through the oxidation of acetyl-CoA.
- **Diminishing Returns:** A principle stating that as fitness levels increase, the rate of improvement decreases, and gains become harder to achieve.
- **Glycolysis (Anaerobic):** An Anaerobic system that supplies ATP to working muscles for 1 to 3 minutes of intense activity through the breakdown of glucose into pyruvate.
- **Individuality:** A training principle acknowledging that each person responds differently to exercise, requiring personalized training plans.
- **Lactate/Lactic acid:** This is a byproduct of glycolysis when the demand for glucose outweighs the oxygen available to help break it down.
- **Progressive Overload:** A training principle that involves gradually increasing the stress placed on the body to stimulate adaptation and improvement.
- **Reversibility:** A training principle describing how fitness gains are lost when training ceases or is significantly reduced.
- **Specificity:** A training principle that states improvements are specific to the type of activity performed; exercises should mimic the desired outcome.
- **Type 1 Muscle Fibres (Slow-Twitch):** Muscle fibres that fatigue slowly, are rich in mitochondria and capillaries, and are adapted for endurance and aerobic activity.
- **Type 2 Muscle Fibres (Fast-Twitch):** Muscle fibres that fatigue quickly, have fewer mitochondria and capillaries, and are adapted for power and anaerobic activity.

OpenAI. (May 27th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

6.9 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. What is the primary function of ATP in the human body?
 - Transports oxygen to muscles
 - Provides energy for muscle contraction and bodily functions
 - Stores glycogen in muscle tissue
 - Converts fat into carbohydrates
2. Which energy system is used for very short bursts of high-intensity activity, such as a 100m sprint?
 - Glycolysis
 - Aerobic metabolism
 - ATP-CP (Phosphagen) system
 - Electron Transport Chain
3. What is a byproduct of glycolysis when oxygen is limited?
 - Creatine phosphate
 - Glucose
 - Lactic acid (lactate)
 - Carbon dioxide
4. Which energy system supports prolonged, moderate-intensity activities like marathon running?

- ATP-CP system
 - Glycolysis
 - Aerobic metabolism (cellular respiration)
 - Anaerobic threshold system
5. What does the principle of progressive overload state?
- Training should stop once the goal is reached
 - Training stress must increase over time for continued improvement
 - Exercise should be avoided if it becomes uncomfortable
 - Only strength training improves fitness
6. Type 1 muscle fibres are best suited for which kind of activity?
- Long-duration aerobic activities like distance running
 - High-intensity, short-duration activities like sprinting
 - Powerlifting competitions
 - Static flexibility exercises
7. According to the principle of individuality, which of the following is true?
- Everyone benefits most from the same workout plan
 - Physical training is only suitable for elite athletes
 - Physical improvements are entirely genetic
 - Training should be tailored to each person's unique needs and conditions
-

Correct Answers:

1. Provides energy for muscle contraction and bodily functions
2. ATP-CP (Phosphagen) system
3. Lactic acid (lactate)
4. Aerobic metabolism (cellular respiration)
5. Training stress must increase over time for continued improvement

6. Long-duration aerobic activities like distance running
7. Training should be tailored to each person's unique needs and conditions

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 7: BIOMECHANICS

Chapter Overview

7.0 Learning Objectives

7.1 What is Biomechanics

7.2 What is Force

7.3 Newton's First Law of Motion

7.4 Newton's Second Law of Motion

7.5 Newton's Third Law of Motion

7.6 Levers

7.7 Stability

7.8 Maximum Force, Range of Motion and Joint Rotation

7.9 Chapter Summary

7.10 Knowledge Check

7.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Define biomechanics and explain how it relates to human movement.
- Differentiate between an internal and external force and how they impact the body.
- Explain Newton's Laws of Motion and how they apply to human movement.
- Describe lever types and identify examples of them in the human body.
- Describe basic biomechanical principles (e.g., COM) and recognize how they impact body stability.

7.1 WHAT IS BIOMECHANICS?

Biomechanics represents a broad class of science which involves the study of movement in living things. This book, however, will focus on the branch of biomechanics concerned with human movement by explaining how forces affect our movement and how to use biomechanics principles to our advantage.

Try This!

To better understand the meaning of Biomechanics, click on each word below to learn more.

Text Description

Bio: “Bio is often a prefix that refers to living things. For example:

- Biochemistry: The study of chemical processes within living things
- Biography: A written account of someone’s life
- Biohazard: A living substance that can be dangerous to other living organisms

Mechanics: “Mechanics” is a branch of science concerned with the interaction between forces and objects.

7.2 WHAT IS FORCE?

To understand how the human body moves, we need a working definition of force. An intuitive definition of **force**—that is, a push or a pull—is a good place to start. A force, which is measured in Newtons (N), is something that acts on or from within the body to either help or hinder movement, and it can come from a variety of sources, either in isolation or simultaneously.

Fitness Fact



“Heavy Box” by Undraw, Undraw License

Remember a time when you were trying to push something heavy. It could have been a dresser, a fridge, or maybe a cabinet. When you tried to push it initially, it likely required a lot of force from you. You may have pushed with your arms, leaned your body forward, dug your feet into the floor, or maybe you did all of that. Once the object finally started moving, suddenly you didn’t have to push so hard. Why is that? Why does the amount of force you need suddenly change? The object did

not get lighter, and you did not get stronger, so what changed?

Well, there are probably more forces acting in this example than you might realize. The following section describes and differentiates between internal and external forces which influence how we move.

External forces

External forces include all forces that originate outside the body. This section will focus on three: gravity, wind, and friction.

Gravity

A constant downward force is exerted on all things on Earth. While other planets, or masses (e.g., stars), have their own gravitational pull, gravity is mentioned in this text, and it refers to Earth's gravity because of its specific impact on human movement and objects.

Example

If your cellphone falls out of your hand or pocket, the force that pulls it to the ground is gravity, which on Earth is 9.81 m/s^2 (meters per second squared).

Wind

A force generated by air flow, sometimes referred to as air resistance. However, wind does not always act as a resisting force if it is happening in a favourable direction.

Example

If you throw a crumpled-up piece of paper in the recycling bin but it misses, the force that acted upon it could have been wind from a fan circulating air in the room.

Friction

A resisting force created by the contact between two surfaces, which, much like wind, can act in favour of or against a desired movement.

Example

If you are walking outside in the winter and slip on a patch of ice hidden beneath the snow, it is likely due to a lack of friction between the ice's surface and the bottom of your shoes.



External Forces: Help or Hinder?

In what ways do external forces (wind, gravity, or friction) help or hinder movement? Move the slider to learn more about wind, gravity, and friction.

Text Description

Slide 1 – Wind

- Hindrance: Driving a golf ball into the wind causes drag.
- Help: The wind propels the sail in a sailboat.

Slide 2 – Gravity

- Hindrance: High Jump.
- Help: Cycling down a hill.

Slide 3 – Friction

- Hindrance: Frictional drag while swimming.
- Help: Friction between the shoes and the rock surface.

Internal Forces

Internal forces include all forces that originate within the body. These forces are typically generated through skeletal muscle contraction. The following types of muscle contractions (as discussed in Chapter 5) act to generate internal forces:

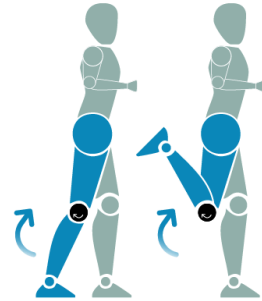
- **Concentric:** A type of muscle contraction that generates force by shortening the muscle.
- **Isometric:** A type of muscle contraction that generates force without changing the length of the muscle.
- **Eccentric:** A type of muscle contraction that generates force while lengthening the muscle.

How do internal forces act within the body? Below are two examples:

Standing Hamstring Curl

Downward Movement:

- Eccentric contraction of the hamstring muscles
- Concentric contraction of the quadriceps muscles
- Knee extends, moving the foot forward



Upward Movement:

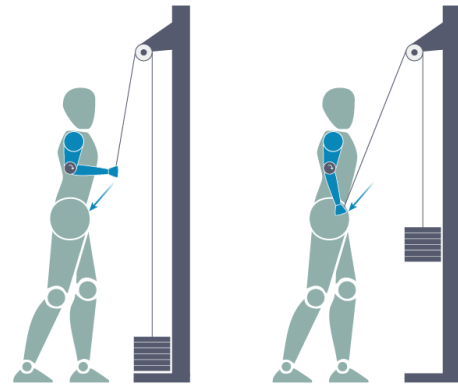
- Concentric contraction of the hamstrings muscles
- Eccentric contraction of the quadriceps muscles
- Knee flexes moving foot toward glutes

“Standing Hamstring Curl using bodyweight” by Koen Liddiard, CC BY-NC-SA 4.0

Standing Tricep Extension

Downward Movement:

- Concentric contraction of the triceps brachii muscles
- Eccentric contraction of the bicep brachii muscles
- Arms extend unilaterally downward and hand grip moves downward



“Standing Tricep Extension with cable machine and hand grip while standing”, by Koen Liddiard, CC BY-NC-SA 4.0

Upward Movement:

- Eccentric contraction of tricep brachii muscles
- Hand grip moves upward
- Isometric contraction of the tricep brachii achieved by holding a partial tricep extension

“4.1 Forces” from Introduction to Biomechanics by Rob Pryce is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

7.3 NEWTON'S FIRST LAW OF MOTION

The Law of Inertia

An object at rest remains at rest or, if in motion, remains in motion at a constant velocity unless acted on by a net external force.

Simply put, this means that an object will maintain its state, whether stationary or in motion, unless acted upon by another force. To understand this law in the context of our own world, imagine a hockey puck on ice. If the puck is stationary, it will not move unless it is pushed by something such as a hockey stick, another puck, or maybe a strong gust of wind. However, to understand the second portion of the law, you have to be a bit imaginative. Although an ice rink is made to be as smooth and slick as possible, so that players can glide around easily, there is still a small amount of friction between the ice and any object in contact with it. However, let's assume that no frictional force exists. In this case, if a hockey puck were hit down the ice, Newton's first law says that it will continue going straight indefinitely, assuming the ice also continues indefinitely.

Gravity, Inertia, and Mass

Gravity and inertia are two closely related aspects in biomechanics that are both connected to mass.

Gravity is the force that pulls us toward the ground and on Earth. It is assumed to be constant at 9.81 m/s^2 .

Mass, measured in kilograms (kg), is the amount of matter in something. Mass is also related to **inertia**, which is the ability of an object to resist changes in its motion—in other words, to resist acceleration. As we know from experience, some objects have more inertia than others. It is more difficult to change the motion of a large boulder than that of a basketball, for example, because the boulder has more mass than the basketball. In other words, the inertia of an object is measured by its mass.

What is the difference between weight and mass?

Often, the term mass is confused and/or used interchangeably with the term weight. However, they do not

mean the same thing. Instead, weight is a measure of gravitation, or gravitational pull, on an object, which can be calculated using both gravity (9.81 m/s^2) and mass (kg). This is because objects with mass are attracted to one another, and that attraction is proportional to the mass of the objects.

Take you and the earth, for example. You have a specific mass (kg), and the Earth's gravity is 9.81 m/s^2 . Therefore, if you multiply those two values, the resulting number would be your weight (N).

$$\text{Your weight (N)} = \text{Your mass (kg)} \times 9.81 \text{ m/s}^2$$

For example, how much do you weigh if your mass is 68 kg?

$$68 \text{ kg} \times 9.81 \text{ m/s}^2 = 667.08 \text{ N}$$

Therefore, if your mass is 68 kg, your weight is 667.08 N.



“How much do I weigh?” Source below

“4.2 Newton’s First Law” from Introduction to Biomechanics by Rob Pryce is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

“How much do you weigh?” image: OpenAI. (2025). ChatGPT. [Large language model].

<https://chat.openai.com/chat> Prompt: Create an illustration of a person who weighs 68kg standing on the Earth. Convert to black and white and remove clouds.

7.4 NEWTON'S SECOND LAW OF MOTION

Law of Acceleration

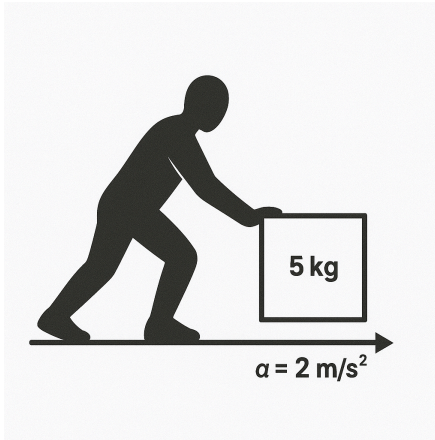
A force applied to an object is directly proportional to the magnitude and direction of the resultant acceleration of that object, but inversely proportional to the object's mass.

$$F = ma$$

- F = Force acting upon an object (N)
 - m = An object's mass (kg)
 - a = Acceleration (m/s^2)

Force, Acceleration, and Velocity

Newton's Second Law of Motion describes a change in motion, but how exactly does that occur? Well, in order for an object to move, a force needs to act upon it. For the object to continuously move, it either needs to have that force acting upon it to be present continuously and/or for momentum to be gained. How that happens is through acceleration.



A 5 kg box is pushed across a floor with an acceleration of 2 m/s^2 . What is the force applied to the box using the equation $F = ma$?

Solution:

$$F = 5 \text{ kg} \times 2 \text{ m/s}^2$$

$$F = 10 \text{ N}$$

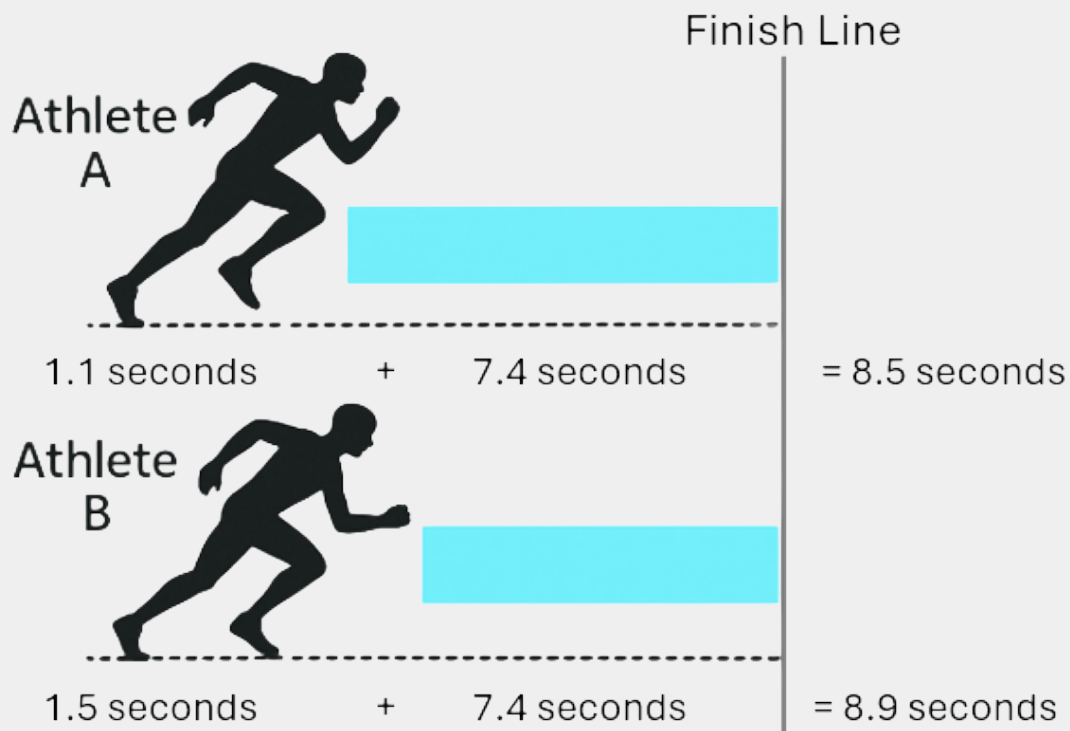
A force of 10 newtons is applied to the box.

Acceleration can be defined as the rate at which an object changes velocity, or simply, how fast or slow an object speeds up or slows down.

This differs from **velocity**, which describes the rate at which an object is moving over time.

Silhouette of a person pushing a 5 kg box across a surface with an acceleration of 2 metres per second squared. Image source below.

Movement in Action



Comparison of two sprinters in a 100m race. Athlete A reaches top speed in 1.1 seconds and finishes the race in 8.5 seconds. Athlete B reaches top speed in 1.5 seconds and finishes in 8.9 seconds. Both maintain top speed for 7.4 seconds, but Athlete A wins due to faster acceleration. Image source below.

Olympic sprinters train year-round to be the fastest people on the planet. However, their velocity (or speed) is not the only thing that matters. Imagine a 100m race with only two athletes. Both athletes have a top speed of 42 km/h, but one athlete reaches the finish line before the other. Why is that? You may want to consider acceleration. How quickly was each athlete able to reach their top speed and maintain it?

Consider the athletes above. Both athletes run at the top speed for 7.4 seconds; however, Athlete A only take 1.1 seconds to reach that top speed, whereas Athlete B

takes 1.5 seconds (0.4 seconds longer). As a result, Athlete A finished 0.4 seconds before Athlete B.

Calculating Acceleration

When calculating acceleration, consider what information you have and choose one of the following two options:

Using Force and Mass

If you know the force applied and the mass of the object, you can calculate the acceleration:

$$a = \frac{F}{m}$$

- a = acceleration (m/s^2)
- F = force (N)
- m = mass (kg)



Using Force and Mass to Calculate Acceleration

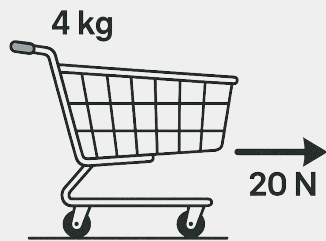


Diagram of a shopping cart with a mass of 4 kilograms being pushed with a force of 20 newtons. Image source below.

A force of 20 N is applied to a shopping cart with a mass of 4 kg. What is the acceleration of the cart using the equation $a = \frac{F}{m}$?

Solution:

$$a = \frac{20 \text{ N}}{4 \text{ kg}}$$

$$a = 5 \text{ m/s}^2$$

The acceleration of the shopping cart is 5 meters per second squared (5 m/s²).

Using Change in Velocity and Time

If you know the initial and final velocity and the time over which the change happens, you can calculate the acceleration:

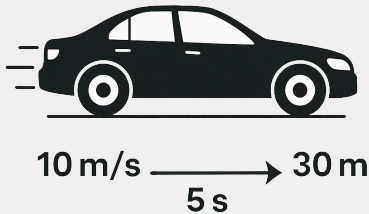
$$a = \frac{\Delta v}{\Delta t}$$

- a = acceleration (m/s^2)
- Δv = change in velocity (final velocity – initial velocity)
- Δt = change in time (time interval over which the change occurs)



Using Change and Velocity to Calculate Acceleration

speeding up



A car speeds up from 10 m/s to 30 m/s in 5 seconds. What is the acceleration using the formula $a = \frac{F}{m}$?

Solution:

Initial velocity (v_i) = 10 m/s

Final velocity (v_f) = 30 m/s

Time (Δt) = 5 s

Plug into the formula here

Diagram of a car speeding up from 10 metres per second to 30 metres per second over a distance of 30 metres in 5 seconds, used to calculate acceleration as 4 metres per second squared using the formula $a = (v_f - v_i) \div t$. Image source below.

$$a = \frac{v_f - v_i}{\Delta t} = \frac{30 \text{ m/s} - 10 \text{ m/s}}{5 \text{ s}} = \frac{20 \text{ m/s}}{5 \text{ s}} = 4 \text{ m/s}^2$$

The car's acceleration is 4 m/s^2 .

Momentum vs Acceleration

Like acceleration, **momentum** involves motion of an object; however, what contributes to momentum differs. As previously noted, acceleration is a product of force and mass (or of $\Delta v \div \Delta t$), while momentum is a product of mass and velocity. This means that if an object is moving, it has momentum that is proportionally equivalent to its mass and its current velocity.

Imagine a beach ball and a bowling ball rolling down a slight hill. They are both rolling toward you at the same velocity (or speed), and you have to stop them both from rolling into your picnic lunch. Which one are you more concerned about? Likely not the beach ball because while it is coming toward you as fast as the bowling ball, it has only a small amount of mass and therefore a small amount of momentum. The bowling ball, however, has much more mass and therefore much more momentum.

To calculate momentum (p), consider the following:

$$p = mv$$

- p = momentum (in kilogram meters per second, $\text{kg}\cdot\text{m/s}$)
- m = mass (in kilograms, kg)
- v = velocity (in meters per second, m/s)

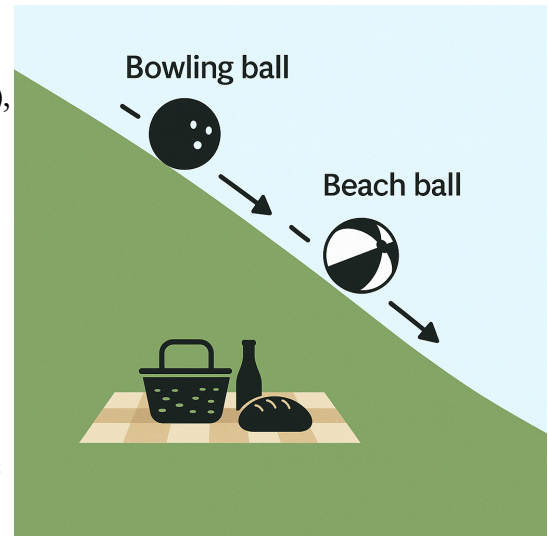
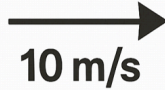


Illustration of a bowling ball and a beach ball rolling downhill toward a picnic. Though both move at the same speed, the bowling ball has greater momentum due to its larger mass, demonstrating that momentum is the product of mass and velocity. Image source below.

Calculating Momentum



0.5 kg



10 m/s

Diagram of a soccer ball with a mass of 0.5 kilograms moving at a velocity of 10 metres per second. Image source below.

A soccer ball has a mass of 0.5 kg and is moving at a velocity of 10 m/s. What is its momentum using the formula $p = mv$?

Solution:

$$p = 0.5 \text{ kg} \times 10 \text{ m/s}$$

$$p = 5 \text{ kg} \cdot \text{m/s}$$

The momentum of the soccer ball is 5 kg m/s.

“Force and Acceleration” image: OpenAI. (2025). ChatGPT. [Large language model].

<https://chat.openai.com/chat> Prompt: A 5 kg box being pushed across a floor with an acceleration of 2 m/s^2 .

“100m dash” image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Using the image provided, draw two athletes in a race, comparing how long it took them to accelerate to their top speed and how that changes the race outcome.

“Shopping cart” image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Create an image of a shopping cart that has a mass of 4kg being pushed with a force of 20 N.

“Speeding car” image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Create an illustration of a car speeding up from 10 m/s to 30 m/s in 5 seconds.

“Momentum” image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Image of a bowling bowl and beach bowl rolling down a hill with a picnic lunch at the bottom.

“Soccer ball” image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: A soccer ball that has a mass of 0.5 kg and is moving at a velocity of 10 m/s.

7.5 NEWTON'S THIRD LAW OF MOTION

The Law of Action and Reaction

For every action, there is an equal and opposite reaction that exists both in magnitude and direction against the object from which the force originated.

To best explain this law, we must define what specific type of force is known as a **‘Normal’ force**.

$$(F_N)$$

This type of force acts upward and is opposite to the force of gravity. Take yourself for example. You are probably sitting in a chair somewhere, reading this resource. In this case, the forces acting upon your body are:

1. The force of gravity
2. The ‘normal’ force



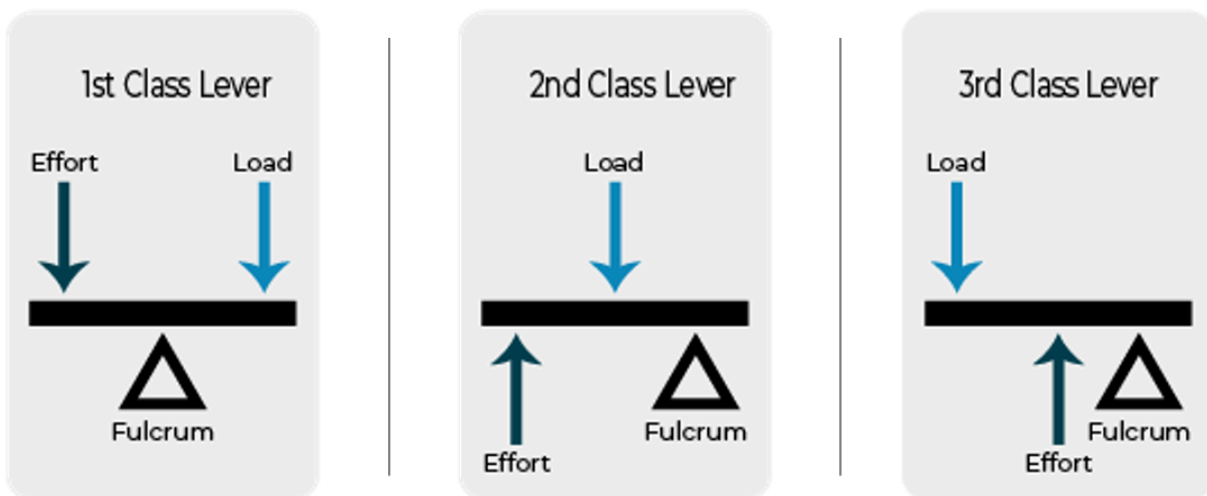
Gravity is pulling everything down, correct? Well, why doesn't it pull you right through your chair onto the floor? Or better yet, why doesn't it pull you straight through the floor or the ground beneath you? It sounds absurd, I know, but it's because a normal force is acting against gravity in an equal but opposite way. The force your body is exerting downward on the chair is equally counteracted by the normal force of that chair on you.

7.6 LEVERS

The human body is made up of bones and muscles, which allow it to move as required. But how exactly do they produce movement? Well, if you have some knowledge of muscles, you might already know that they produce movement by contracting where, when, and how much we need them to. However, because the body is complex and requires sophisticated movements in a variety of planes, how bones and muscles are connected differs throughout the body.

Bones and muscles act together, as a lever, to move the body. Within each **lever system** are the following components:

- **Lever Arm:** A “bar-like” structure which is used to transmit force.
- **Fulcrum:** Where the lever arm (or joint) pivots. Also known as “axis of rotation”.
- **Resistive Force (Load):** Force acting to prevent motion.
- **Applied Force (Effort):** Typically causes the motion and is often triggered via muscle contraction.



“Levers” by Koen Liddiard, CC BY-NC-SA 4.0

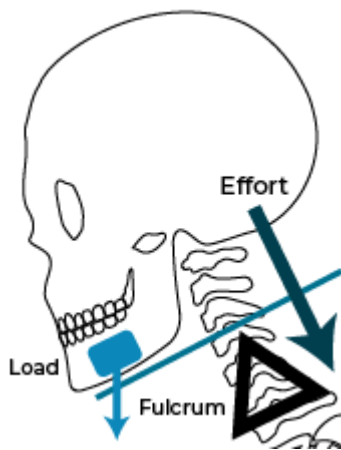
When arranged differently, these components can help the body:

1. Balance two or more forces;

2. Provide a force advantage where less effort is required to overcome a greater resistance, or;
3. Provide an advantage in speed of movement whereby the load moves further and faster than the effort force.

Levers within the body accomplish this by existing as either a first, second, or third-class lever:

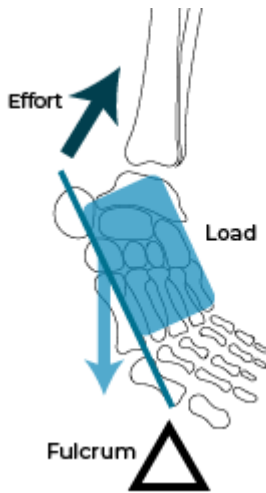
Class Levers



First-class levers are the simplest types of lever, where the two forces, the load and the effort, are applied on opposite sides of the fulcrum. In the body, the best example of a first-class lever is the way your head is raised off your chest. With the atlanto-occipital joint (the spinal column-skull joint) acting as the fulcrum, the posterior neck muscles produce the effort, and the mass of the facial skeleton is the resistance. When you lift your head up and down, this lever system acts like a seesaw.

“First-class lever” by Koen Liddiard, CC BY-NC-SA 4.0

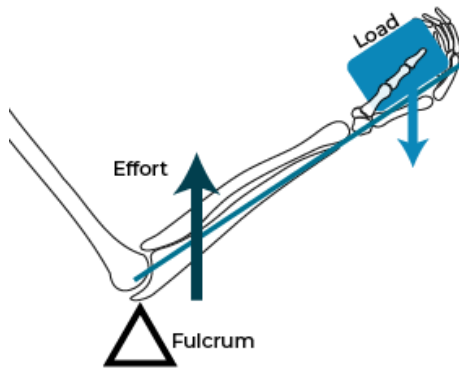
Second-Class Levers



“2nd lever” by Koen Liddiard, CC BY-NC-SA 4.0

Second-class levers differ in that the load and the effort exist on the same side relative to the fulcrum. The effort, however, is closer to the load than the fulcrum, which allows a large resistance to be moved by a small amount of effort. However, this means that the resistance will be moved at a relatively slow pace and can only be moved a short distance. An example of this within the body would be your calf muscles. In this scenario, the weight of your body acts as the load, your calf muscles as the effort, and the balls of your feet as the fulcrum.

Third-Class Levers



"3rd lever" by Koen Liddiard, CC BY-NC-SA 4.0

Third-class levers are the most common type of lever in your body. The effort is applied between the fulcrum and the resistance, which allows the resistance to be moved relatively quickly over large distances. An example within the body is when you lift your hand by flexing your biceps brachii. In this scenario, your elbow acts as the fulcrum, the biceps brachii produces the effort, and the weight of your hand is the load being lifted.

"Chapter 12. Biomechanics" from Human Anatomy and Physiology I by Priscilla Stewart is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

7.7 STABILITY

Body stability is a crucial component of our ability to move effectively. Without it, our ability to complete daily tasks and participate in physical activity becomes impaired, potentially putting us at risk for injury.

Stability can be defined as the ability of an object to maintain or return to a position of equilibrium when acted upon by external forces. Within the bounds of this course, stability depends on four distinct factors:

- Mass
- Centre of Mass (COM)
- Base of Support (BOS)
- Position of COM

Mass

A person's mass consists of all the materials that make up their given body. While this includes the physical body and tissue composition of an individual, it can also include anything connected to or layered on top of that body. This includes but is not limited to hand-held objects (e.g., bats, dumbbells, sticks, etc.), protective equipment (e.g., pads or helmets), and clothing (e.g., ski boots).

As discussed in relation to Newton's Second Law of Motion: The Law of Acceleration, the greater the mass, the greater the force required to move that mass. Using football players as an example, think of the types of bodies you may see in the position of a defensive tackle, the players whose job it is to act as a wall to prevent any movement of the offence down the field. Athletes in this role are typically tall, wide and have a large mass. This mass works to their advantage by making it difficult for them to be moved.

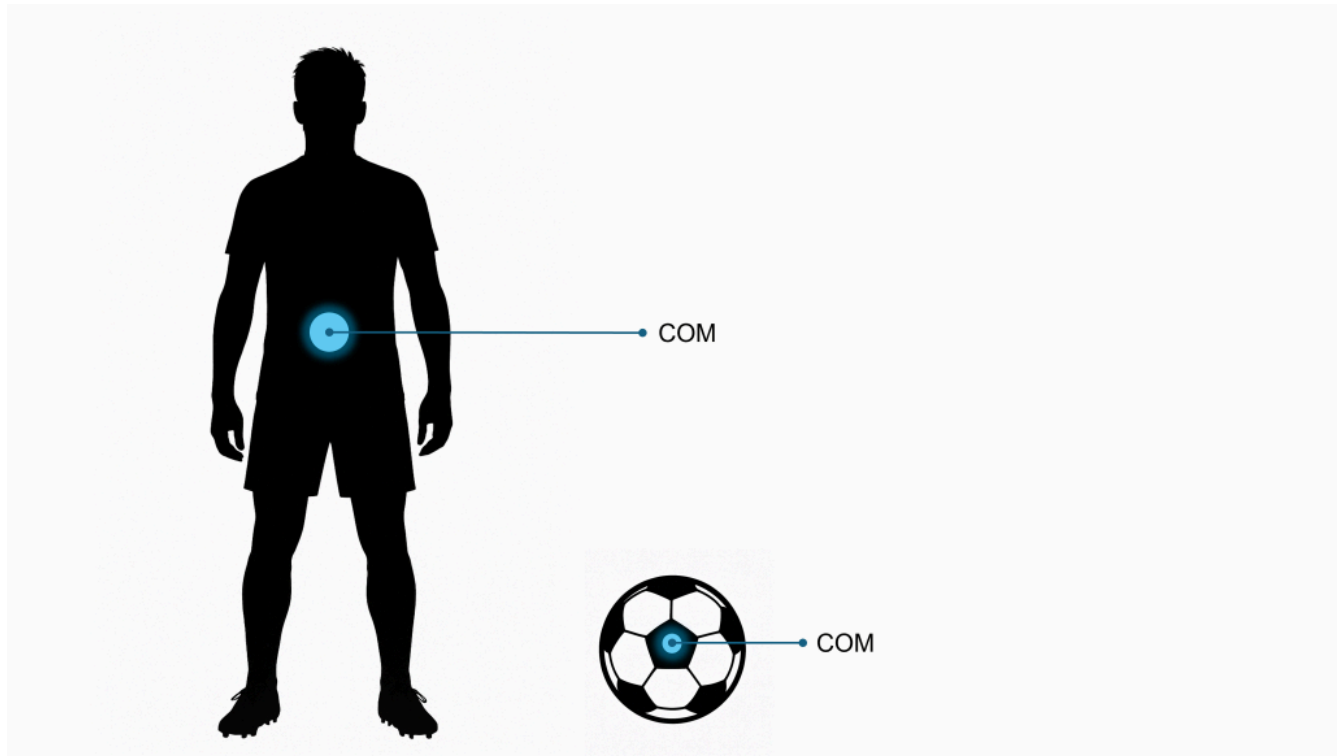


"Football" by Pixabay, Pexels License

Centre of Mass (COM) and Base of Support (BOS)

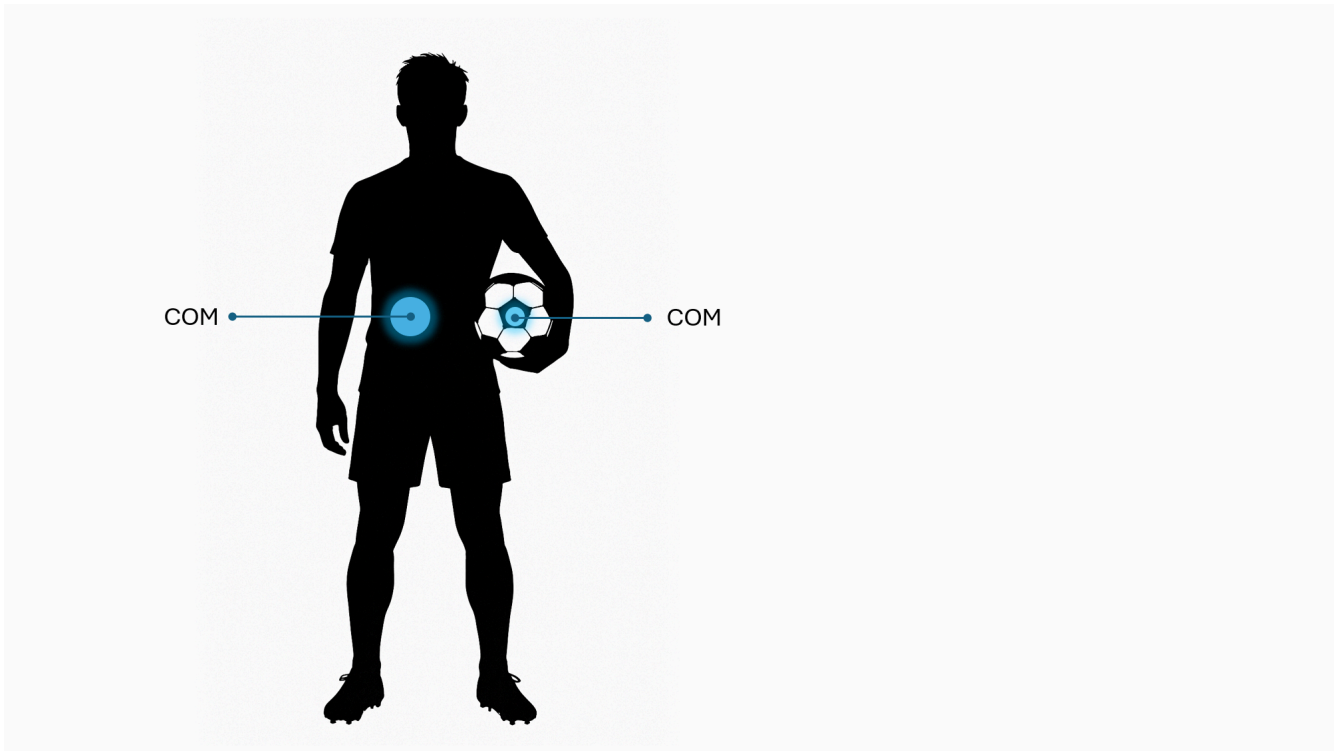
Although an increased mass does contribute to bodily stability, your **COM** and its relation to your **BOS** play

an even greater determining role. As per its name, COM is the imaginary center point at which the mass of an object is equally distributed. While this point is easily imagined in an object such as a ball, where the COM would exist at the centre point of the ball, the COM within the human body is harder to pinpoint. This is because, although the body is generally symmetrical side to side, the human body is not created equal in all orientations, and it is constantly moving, meaning the location of your COM can change.



This image illustrates the concept of the center of mass (COM) and compares the location of the center of mass for a human body with a soccer ball. Image source below.

Your COM is fluid and changes with your body's movements and weight distribution, and can even exist outside of the body's bounds. Consider the following image, where you have a human body holding a ball. Because the ball being held has mass, the bodies' total mass and distribution are altered, shifting the COM to a new position.



This image illustrates how your COM changes with body movements and weight distribution. Image source below.

Position of COM

Generally speaking, the closer to the ground your COM is, the more stable your body will be. However, this is not always the case. To maintain stability, the BOS also needs to be considered in relation to COM. BOS represents the support area beneath an object or body that is defined by all points of contact with that surface (feet, hands or any other body part). Like COM, your BOS changes both as you move and depending on the number and positioning of your points of contact.

How we maintain stability is this: if your COM falls over or within your BOS, you will remain stable, but if your COM falls outside your BOS, stability will be lost.

Movement in Action

Have you ever wondered why individuals who are crouched, with their feet far apart and their bodies hunched forward, look intimidating? Maybe, but there is also a biomechanical explanation for it. Martial arts professionals, who practice Karate or Taekwondo, modify their COM and BOS to their advantage. By lowering themselves closer to the ground, they lower their COM, making them less vulnerable to instability or being pushed off their feet. And by standing with their feet far apart, they increase the size of their BOS whilst keeping their COM within it.



“Girl Sport” by RDNE Stock Project, Pexels License

Definition of stability: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Define stability in biomechanical terms.

“COM” images: OpenAI. (2025). *ChatGPT*. [Large language model]. <https://chat.openai.com/chat> Prompt:

Silhouette of a soccer player holding a ball and facing forward. The ball is under their left arm. Image of the same soccer player, but not holding the ball. Image of just the soccer ball.

7.8 MAXIMUM FORCE, RANGE OF MOTION, AND JOINT ROTATION

Maximum Force



Another biomechanical principle includes the concept of maximum force. **Maximum force** refers to an individual exerting maximum effort when completing a physical task. To achieve this, it takes more than just strength. Maximum force requires all possible joint movements that could contribute to the movement, using their full range of motion (ROM), and with appropriate sequencing.

“Barbell” by Anastasia Shuraeva, Pexels License

Range of Motion (ROM)

Range of motion (ROM), while a factor of maximum force, is also a factor in movement efficiency and an indicator of flexibility. It can be defined as the measure through which a joint moves through its full movement potential, or movement at a joint from a position of full flexion to full extension.



Kneeling lunge



Frog Squat



90/90 Stretch

Illustration of three flexibility exercises that promote joint range of motion: a kneeling lunge for the hip flexors, a frog squat for the hips and ankles, and a 90/90 stretch targeting hip rotation. These stretches help improve movement efficiency and flexibility. Image by Koen Liddiard, CC BY-NC-SA 4.0

 Try This!

Test your own ROM by using either your hip or shoulder. When doing so, be sure to move gently, acknowledging any discomfort or movement that feels interrupted. These may be signs of obstructed range of motion due to anything from tight muscles, musculoskeletal injuries, or joint conditions.

Video: “7-Minute Hip Mobility Workout (Fix Tight Hips)” by nourishmovelove [8:41] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Video: “10-Minute Shoulder Mobility Routine (Bulletproof Shoulders)” by nourishmovelove [9:48] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

Sequencing of Joint Rotation

The last of this chapter’s biomechanical principles is joint sequencing. In addition to ROM contributing to achieving maximum force, joint sequencing is required to make our movements as effective as possible.

Sequencing of joint rotation refers to the idea that when attempting to achieve maximum force, the best possible strategy is to use joints specifically from large to small. What this means is rotating and utilizing joints which activate large muscles before moving onto small joints and muscles.



Movement in Action: Tennis Serve of Carlos Alcaraz

Video: “Carlos Alcaraz Serve in Slow-mo. It’s a thing of beauty. #tennis #serve #carlosalcaraz” by PlayYourCourt.com [0:24] is licensed under the Standard YouTube License. *Music only.*

Text Description

Consider what you see in this tennis serve:

1. If you pause the video at 5 seconds, the athlete bends at the knees and hip slightly to jump; these are the larger joints which activate and utilize large lower leg muscles.
2. Next, at 14 seconds, they extend their shoulder, bringing the racket up and then in front of their body. This movement utilizes slightly smaller muscles located in the upper back, shoulder, and chest.
3. After that, at 17 seconds, they extend their elbow, which uses their triceps brachii muscle (an even smaller muscle), to bring the racket in contact with the ball.
4. And finally, quickly after the 17-second mark, they flex their wrist using the flexors in their forearms (which are the smallest muscles in this example) during the follow-through movement of their serve.

Try This!

See for yourself how crucial the sequencing of joint rotation is to movement by trying this exercise at home.

Grab a rolled-up pair of socks and stand facing the direction you are going to throw them. This will act as our projectile (you are welcome to use a real ball; however, socks are the house-friendly option).

Complete the three throws using the following guidelines:

- Throw #1: Standing upright holding the socks, position your arm at a 90-degree angle with your upper arm parallel to the floor and your forearm perpendicular to it. Using only your wrist, throw the socks as far as you can (Hint: hold your opposite hand in front of your forearm if you cannot prevent your arm from moving as you throw). Record how far it went.
- Throw #2: Assuming a similar starting position, but now using your wrist and elbow joint, throw the sock as far as you can. Record how far it went.
- Throw #3: Assuming a similar starting position, but now using your wrist, elbow, and shoulder joint, throw the sock as far as you can. Record how far it went.

If done correctly, the throw attempts 1 to 3 should have increased in distance thrown. This is because each throw, aside from the first throw, used adding sequencing of joints compared to the previous throw.



Photo by Maah Hos, Unsplash
License Cropped

7.9 CHAPTER SUMMARY

Key Takeaways

- **Biomechanics bridges biology and mechanics:** Biomechanics is the scientific study of how forces interact with living bodies, especially human movement. It combines knowledge of living systems (“bio”) and physical forces (“mechanics”) to explain how motion occurs and how it can be optimized.
- **Forces influence movement and come from inside and outside the body:** Internal forces, such as muscle contractions (concentric, eccentric, isometric), originate within the body, while external forces like gravity, wind, and friction come from the environment and impact our movement capabilities and stability.
- **Newton’s Laws of Motion:**
 - The First Law (Inertia) explains that an object at rest remains at rest, or if in motion, remains in motion at a constant velocity unless acted on by a net external force.
 - The Second law ($F = ma$) explains that a force applied to an object is directly proportional to the magnitude and direction of the resultant acceleration of that object, but inversely proportional to the object’s mass.
 - The Third law explains that for every action, there is an equal and opposite reaction that exists both in magnitude and direction against the object from which the force originated.
- **Three classes of Levers in the body to aid movement:** The body uses three types of levers involving bones, joints (fulcrums), and muscles.
 - **First-class:** balanced motion (e.g., head nodding).

- **Second-class:** strength advantage (e.g., calf raise).
- **Third-class:** speed and range advantage (e.g., biceps curl).
- **Stability depends on mass, COM, and BOS:** Stability is greatest when the center of mass (COM) is low and falls within a wide base of support (BOS). Adjusting body posture and contact points helps maintain or regain equilibrium, especially during movement or impact.
- **Maximum force requires full joint movement and proper sequencing:** To generate maximum force in movement (e.g., throwing or serving), the body must utilize its full range of motion (ROM) and coordinate joint activation from large to small muscle groups in the correct order.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>
 Prompt: Summarize the following content into six key takeaways.

Key Terms

- **Acceleration:** The rate at which an object changes velocity or how fast or slow an object speeds up or slows down.
- **Applied Force (Effort):** Typically causes the motion and is often triggered via muscle contraction.
- **Base of support (BOS):** The area beneath a person or object that includes every point of contact that supports it against gravity (feet, hands or any other body part touching the ground or another surface). A larger and wider BOS increases stability.

- **Biomechanics:** A broad class of science which involves the study of movement in living things.
- **Centre of mass (COM):** The imaginary center point at which the mass of an object is equally distributed.
- **External forces:** All forces that originate outside the body, such as gravity (9.81 m/s^2), wind, and friction.
- **Force:** A force, which is measured in Newtons (N), is something that acts on or from within the body to either help or hinder movement, and it can come from a variety of sources, either in isolation or simultaneously.
- **Fulcrum:** Where the lever arm (or joint) pivots. Also known as “axis of rotation”.
- **Gravity:** This is the force that pulls us toward the ground and on Earth. It is assumed to be constant at 9.81 m/s^2 .
- **Inertia:** The ability of an object to resist changes in its motion (resist acceleration)
- **Internal forces:** All forces that originate within the body. These forces are typically generated through skeletal muscle contraction (concentric, isometric, eccentric).
- **Lever Arm:** A “bar-like” structure which is used to transmit force.
- **Lever system:** A lever system contains a lever arm, a fulcrum, a resistive force (or load), and an applied force (or effort). There are three classes of levers which describe different configurations of those key lever system components (First, second, and third-class levers).
- **Mass:** Mass is measured in kilograms (kg) and is the amount of matter in something. A person’s mass consists of all the materials that make up their given body and can also include anything connected to or layered on top of their body.
- **Maximum force:** Refers to an individual exerting maximum effort when completing a physical task using their full range of motion with appropriate sequencing.
- **Momentum:** The motion of an object that is related to its mass and velocity.
- **Normal Force:** Acts upward and is opposite to the force of gravity.
- **Range of motion (ROM):** The measure through which a joint moves through its full movement potential, or the movement at a joint from a position of full flexion to full extension.

- **Resistive Force (Load):** Force acting to prevent motion.
 - **Sequencing of joint rotation:** Refers to the idea that when attempting to achieve maximum force, the best possible strategy is to use joints specifically from large to small. What this means is rotating and utilizing joints which activate large muscles before moving onto small joints and muscles.
 - **Stability:** The ability of an object to maintain or return to a position of equilibrium when acted upon by external forces.
 - **Velocity:** The rate at which an object is moving over time.
 - **Weight:** The measure of gravitation or gravitational pull on an object, which can be calculated using both gravity and mass.
-

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

7.10 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. What is the best definition of biomechanics as it relates to human movement?

- The study of movement in living things, especially how forces affect movement
- The study of chemical processes within living things.
- The measurement of athletic performance
- The study of life sciences in the body

2. Which of the following is an example of an external force acting on the body?

- Muscle contraction
- Ligament tension
- Gravity pulling a phone to the ground
- Joint rotation

3. According to Newton's First Law of Motion, an object in motion will remain in motion unless:

- It gains more speed
- Its internal energy increases
- Its mass is reduced
- A net external force acts upon it

4. What type of lever is used when the biceps brachii lifts the forearm at the elbow joint?

- Third-class lever
- First-class lever
- Fourth-class lever
- Second-class lever

5. Which biomechanical factor(s) contribute to body stability?

- Low mass
- COM within BOS
- Large ROM
- Low mass and COM within BOS

6. During the upward or flexion phase of a bicep curl, the bicep brachii muscle engages in which type of skeletal muscle contraction?

- Isokinetic
- Concentric
- Isometric
- Eccentric

7. During maximum force generation, what is the optimal sequence of joint rotation?

- From large to small joints
- From smallest to largest joints
- Random joint order
- From upper to lower body joints

Answers:

1. The study of movement in living things, especially how forces affect movement
2. Gravity pulling a phone to the ground
3. A net external force acts upon it
4. Third-class lever

5. Centre of mass within the base of support
6. Concentric
7. From large to small joints

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>

Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 8: UPPER BODY EXERCISES

Chapter Overview

8.0 Learning Objectives

8.1 Muscular Strength vs Muscular Endurance

8.2 Basic Upper Body Exercises: Free Body

8.3 Basic Upper Body Exercises: Free Weights or Machine-Based

8.4 Resistance Training Splits and Workout Structures

8.5 Chapter Summary

8.6 Knowledge Check

8.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Highlight the key similarities and differences between muscular strength and muscular endurance, as well as how to effectively implement both into a training program.
- Describe the form, common mistakes, and modifications associated with various upper-body exercises.
- Identify different training splits as well as their advantages and drawbacks depending on an individual's level of experience.
- Differentiate various workouts and structures and understand how each could be strategically implemented into a training regimen.

This chapter, as well as Chapter 9, will have a practical focus and can be used as a guide for physical activity and resistance training. Although these two chapters convey both theoretical and applied content, readers are encouraged to learn by doing and incorporate the concepts into their personal exercise regimens.

Within this chapter, we will examine how muscular strength differs from muscular endurance from both a training and physiological perspective. We will also discuss the muscles activated, form, common mistakes, and manipulations to



Photo by [Andrea Piacquadio](#), Pexels License

numerous key upper-body exercises. Lastly, we will explore training splits and workout structures that we can use to program and apply these exercises.

8.1 MUSCULAR STRENGTH VS MUSCULAR ENDURANCE

Whether associated with upper or lower body exercise, the concept of physical fitness is typically composed of the following five key elements (Healthline, 2022, para 3):

1. Body Composition
2. Cardiorespiratory Endurance
3. Flexibility
4. **Muscular Strength**
5. **Muscular Endurance**



Muscular strength versus muscular endurance. Photo (left) by Ketut Subiyanto, Pexels License, Photo (right) by RUN 4 FFWPU, Pexels License, Colour modified.

Comparing Muscular Strength and Endurance

When specifically examining upper body exercises, most of the benefits to one's overall physical fitness are produced by improvements to both **muscular strength** and **muscular endurance**. While these two elements are quite similar and are often used synonymously, there are differences in how we can prioritize each of them through training.

Item	Muscular Strength	Muscular Endurance
Definition (LifeFitness, 2024, para 3 & 4)	The ability to produce maximal force for short periods of time	The ability to produce lesser amounts of force for extended periods of
Weight/Resistance (Schoenfeld et al, 2021)	80 to 100% 1RM	<60% 1RM
Repetitions (Schoenfeld et al, 2021)	1 to 5	15+
Muscle Fibres (Golden, 2025)	Large recruitment of fast-twitch (Type II) muscle fibres	Large recruitment of slow-twitch (Type I) muscle fibres
Energy Systems (Golden, 2025)	Primarily anaerobic	Increasingly aerobic as repetitions increase
Physiological Adaptations (Schoenfeld et al, 2021)	Training-related increases in neuromuscular efficiency (how well the nervous system recruits and contracts muscle fibres) and coordination contribute to increases in muscular strength	Training-related increases in metabolic activity (how efficiently oxygen can be delivered and used to create usable muscular energy) contribute to increases in muscular endurance

This table does not include weight/resistance from 60 to 80% 1RM or repetitions between 6 and 14. Although both muscular strength and endurance can be improved using weights and repetitions that fall within these ranges, most repetition continuums define these ranges as prioritizing muscular hypertrophy (i.e., muscle growth). It is, however, important to note that although they provide approximate guidelines, repetition continuums may oversimplify the relationship between muscular strength, endurance, and hypertrophy. Each of these factors can be improved across a range of resistance and repetition schemes and is highly dependent on overall training volume and effort (Schoenfeld et al, 2021).

This information highlights the importance of incorporating a variety of resistance and repetition schemes into a training regimen if one is trying to maximize the benefits to their overall physical fitness.

Fitness Fact



“Personal trainer” by
Undraw, Undraw
License

Research by Helms et al (2018) and Krzysztofik et al. (2019) suggests that hypertrophy can occur (muscle can be built) with sets as high as 30+ repetitions as long as an individual is nearing muscular failure (the point at which another repetition is not possible) when completing their final repetitions of a given set. Nearing muscular failure is typically defined as having 1 to 4 repetitions in reserve, meaning an individual is 1 to 4 repetitions away from muscular failure.

8.2 BASIC UPPER BODY EXERCISES: FREE BODY

The following section will highlight several upper-body exercises and convey information, including the purpose of the exercise, proper form, common mistakes, and modifications. When performing any of the following exercises, the following guidelines will help improve efficiency and reduce the risk of injury.

- Always maintain a neutral spine from the crown of your head to the base of your tailbone (think about stacking each vertebrae/disc of your spine in its anatomical position).
 - The head and neck should never be flexed forward or extended backward.
 - Shoulders should never be rounded or elevated.
 - The lower back should never be overly flexed, extended, or rounded.
- All movement should be conducted in a controlled manner: While some activity specifically uses explosive movement, basic physical activity is most beneficial, practical, and safe when conducted in a smooth, consistent, and completely controlled manner.
- Core or abdominal engagement should always be maintained to protect the spine and trunk from injury. This will also create rigidity and structure in your entire body, increasing stability and allowing other muscles to produce force more efficiently.
- The following exercises have several variations that involve changes in body positioning/biomechanics, the type of force (barbell, dumbbell, kettlebell, cables/pulleys, resistance bands) and the direction of the force relative to the body's position.

Plank

Agonist muscles include the rectus abdominis and external obliques. Many synergist and stabilizer muscles are found throughout the body during an isometric plank.



“Fit woman doing a plank on yoga mat” by Ivan Radic, CC BY 2.0

Form and movement:

- The movement is held in the prone position with the hands or forearms contacting the ground directly below the shoulders.
- The plank is a unique exercise given that, if executed correctly, there is very little (if any) movement, given the many isometric contractions being held in unison.

Common mistakes (and how to avoid them):

- Midsection (abdominal and gluteal region) “sagging” towards the ground (ensure musculature in this region is contracted to maintain a neutral spine/posture).

Modification:

- The second point of contact with the ground can be manipulated to alter the body’s lever arm and increase or decrease movement difficulty. By having the feet or knees act as the second point of contact, one can increase or decrease the lever arm/difficulty, respectively.
- External load can be used to increase difficulty (i.e., a plate positioned on the upper, mid, or low back).
- A side plank can emphasize the external obliques, forcing these muscles to isometrically contract to avoid the body moving towards the ground.



Push-up

Agonist muscles include the pectoralis major and triceps brachii. The deltoids act as synergist muscles for the movement, and many muscles (including core musculature and the hip flexor group) are recruited as stabilizers.



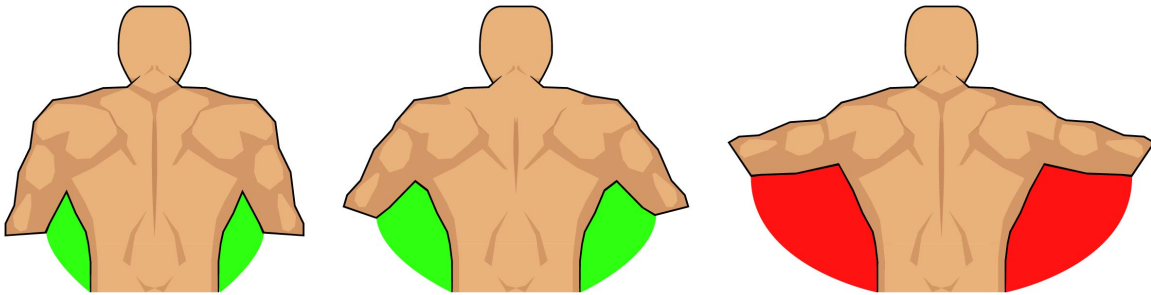
“Man doing push-ups” by Ivan Samkov, Pexels License

Form and movement:

- Movement begins in the prone plank position with hands contacting the ground directly under the shoulder joint.
- The body moves downwards through controlled eccentric contraction, causing extension of the shoulder and flexion of the elbow.
- Once the desired depth has been achieved, controlled concentric contraction causes shoulder flexion and elbow extension, returning the body to its starting position.

Common mistakes (and how to avoid them):

- Hands placed too wide, causing the shoulder joint angle to be $\geq 90^\circ$, increasing risk of injury (position hands narrow enough to achieve a shoulder joint angle of $< 90^\circ$).
- A person standing in different poses.
- Midsection (abdominal and gluteal region) “sagging” towards the ground (ensure musculature in this region is contracted to maintain a neutral spine/posture).



This image shows three illustrations of different push-up positions and arm placement. Green represents a more optimal or safe position, and red represent a less optimal or riskier position. Image by Koen Liddiard, CC BY-NC-SA 4.0

Modification:

- The second point of contact with the ground can be manipulated to alter the body's lever and increase or decrease movement difficulty. By having the feet or knees act as the second point of contact, one can increase or decrease the lever arm and difficulty, respectively.
- External load or resistance bands can be used to increase difficulty. (i.e., a plate positioned on the upper back; or a resistance band looped under the hands and around the upper back).
- Hand position can be narrower to increase activation of the triceps brachii.



8.3 BASIC UPPER BODY EXERCISES: FREE WEIGHTS OR MACHINE-BASED

Chest Press

Agonist muscles include the pectoralis major. The deltoids and triceps brachii act as synergist muscles for the movement, and many muscles (including core musculature, lower body musculature, and back musculature) are recruited as stabilizers.



“Man lying by doing barbell” by Bruno Beueno, Pexels License

Form and movement:

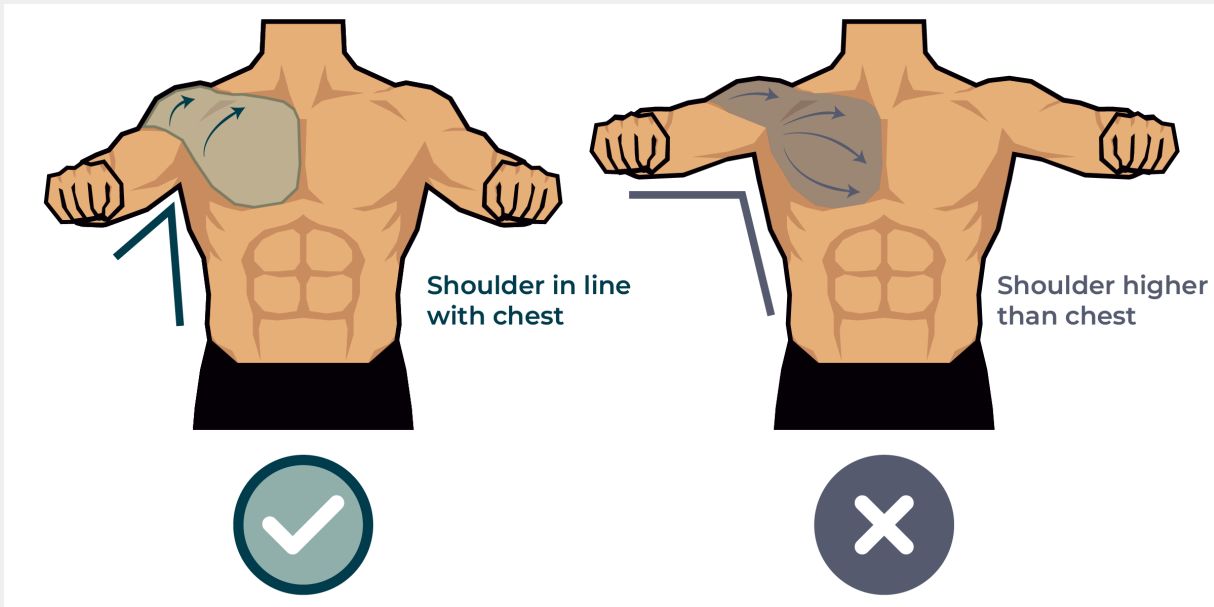
- Movement most commonly begins in the supine position with the back anchored by a bench and the feet firmly planted into the ground.
- Whether using a barbell or dumbbells, the movement begins with the controlled lowering of the external load through eccentric contraction, causing extension of the shoulder and flexion of the elbow.
- Once the desired depth has been achieved, the movement continues with the controlled pressing of the external load through concentric contraction, causing flexion of the shoulder and extension of the elbow to return the barbell or dumbbell to its initial position.

Common mistakes (and how to avoid them):

- Hands placed too wide, causing the shoulder joint angle to be $>90^\circ$, increasing risk

of injury (position hands narrow enough to achieve a shoulder joint angle of $<90^\circ$)

- Legs are not actively pressed into the ground, and core musculature is not contracted, which decreases the body's overall stability.



Correct shoulder joint angle ($<90^\circ$) versus incorrect shoulder joint angle ($>90^\circ$). Image by Koen Liddiard, CC BY-NC-SA 4.0

Modification:

- Hand position on a barbell can be narrower to increase activation of the triceps brachii by increasing the amount of elbow extension the movement requires.
- The angle of the bench can be altered to manipulate the position of the shoulder relative to the trunk, creating greater emphasis/recruitment on upper and lower muscle fibres of the pectoralis major during incline and decline presses, respectively.



Pull-down or Pull-up

Agonist muscles include the latissimus dorsi. The biceps brachii and deltoids act as synergist muscles for the movement. Given the instability of the pull-up compared to the seated pull-down, many more muscles (such as those of the core and the lower body) will be recruited as stabilizers during a pull-up as opposed to the more stable pull-down.

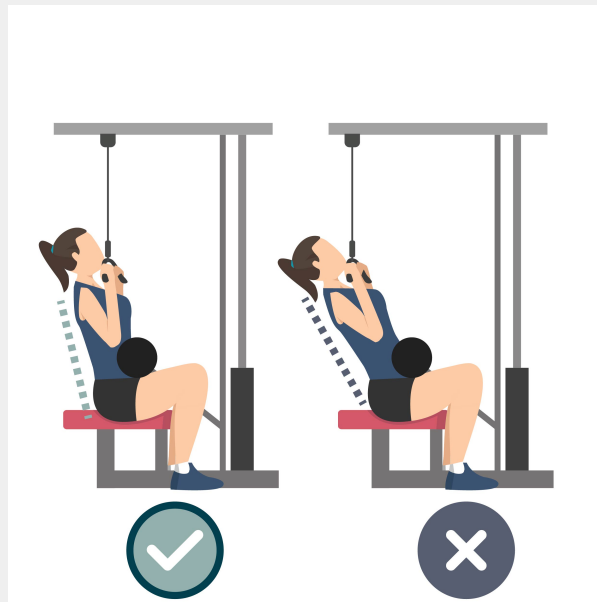


Photo by Kampus Production, Pexels License

Form and movement:

- Movement begins with the hands placed on the bar just outside of shoulder width apart.
- During a pull-up, the latissimus dorsi is recruited to produce adduction and extension of the shoulder joint, pulling the body up towards the bar. Once the chin is over the bar or the bar touches the clavicle, one controls the movement back to the starting position using eccentric contractions.
- During a pull-down, the latissimus dorsi is recruited to produce adduction and extension of the shoulder joint, pulling the bar down towards the body. Once the bar is below the chin or the bar touches the clavicle, one controls the bar back to the starting position using eccentric contractions.

Common mistakes (and how to avoid them):



Correct position versus leaning too far back during a pull-down. Image by Koen Liddiard, CC BY-NC-SA 4.0

- Core and lower body musculature not engaged during a pull-up, creating a large amount of instability, and wasted force production (ensure core is braced and lower body muscles are contracted prior to initiating each repetition of the movement)
- Leaning too far back during a pull-down (the upper body should be leaned back 10 to 20° to position the latissimus dorsi in the most productive position to produce force).

Modification:

- Hand position on the bar can greatly modify the movement; using a neutral or supinated grip as opposed to a pronated grip will increase recruitment of the biceps brachii.



Shoulder Press

Agonist muscles include the deltoids. The triceps brachii act as synergist muscles for the movement. Stabilizer muscles will vary based on whether the movement is done seated, with a machine or using free weights. As the instability of the movement increases (free weights being the most unstable and machines being the most stable), more stabilizer muscles will be recruited. Common stabilizer muscles will include the erector spinae group, lower body musculature, rotator cuff muscles, and core muscles, to name a few.



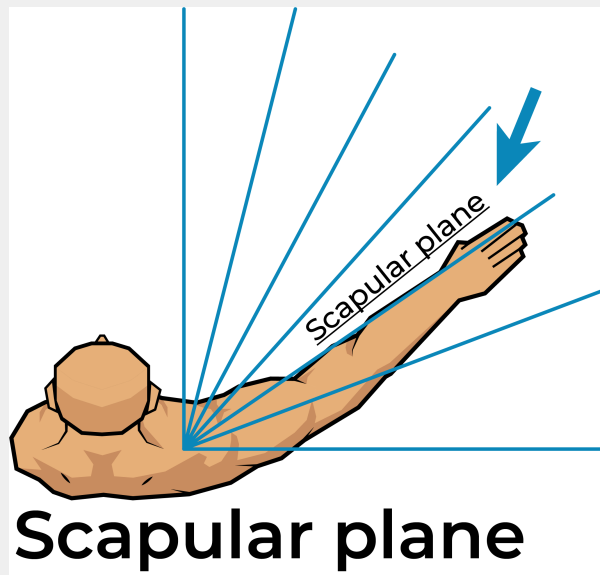
“A Man Doing a Dumbbell Shoulder Press” by Alesia Kozik, Pexels License

Form and movement:

- Movement begins with the hands placed on the external load (bar, dumbbells, machine handles) near the shoulder joint.
- The movement is initiated by the deltoids and triceps brachii contracting to abduct and flex the shoulder joint and extend the elbow joint, moving the external load overhead.
- Once the concentric portion of the movement is complete, the same musculature controls the weight back to the starting point of the movement using eccentric contractions.

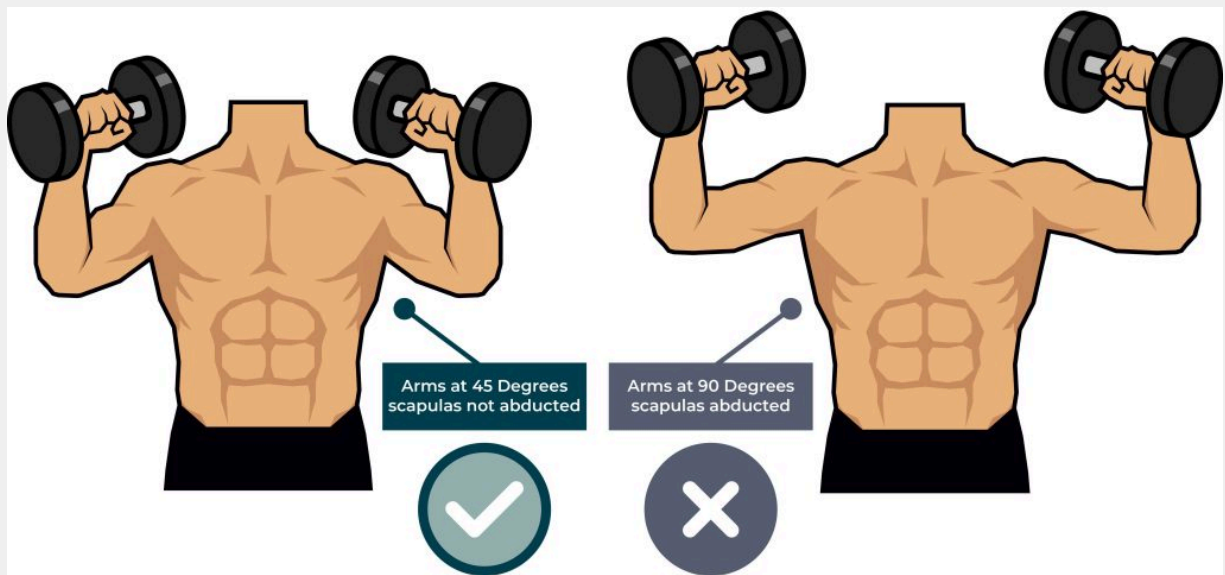
Common mistakes (and how to avoid them):

- Pressing conducted with the arms too far in front of the body or too far to the side of the body (for optimal force production and safety, overhead pressing should be done in the scapular plane – located between the frontal and sagittal plane)



Location of the scapular plane. Image by Koen Liddiard, CC BY-NC-SA 4.0

- Rounding of the lumbar spine is commonly seen with this movement to increase activation of the upper fibres of the pectoralis major (mimicking an incline chest press), which places the low back at a heightened risk of injury (ensure spinal erectors and anterior core muscles are contracted to maintain a strong and neutral posture/spinal alignment).



Correct positioning (arms at 45 degrees) versus incorrect positioning (arms at 90 degrees). Image by Koen Liddiard, CC BY-NC-SA 4.0

Modification:

- Overhead pressing is mainly manipulated by altering the external load (barbell, dumbbell, kettlebell, resistance band, machine, etc.).



Click to watch
video

Horizontal Row

Agonist muscles include the latissimus dorsi and trapezius. The biceps brachii and deltoids act as synergist muscles for the movement. Stabilizer muscles will vary based on whether the movement is done seated, with a machine or using free weights. As the instability of the movement increases (free weights being the most unstable and machines being the most stable), more stabilizer muscles will be recruited. Common stabilizer muscles include the erector spinae group, hamstrings group, gluteus maximus, and core muscles, to name a few.



Photo by Andres Ayrton, Pexels License

Form and movement:

- Movement begins with the hands placed on the external load (bar, dumbbells, machine handles) away from the body.
- The movement is initiated by the trapezius and latissimus dorsi contracting to retract the scapula, adduct & extend the shoulder, and flex the elbow joint until the external load is fully pulled towards the low abdominal region.
- Once the concentric portion of the movement is complete, the same musculature controls the weight back to the starting point of the movement using eccentric contractions.

Common mistakes (and how to avoid them):

- Elevation of the scapula and shoulder joint which increases the risk of injury and decreases force production (ensure scapula and shoulders are depressed and retracted prior to initiating the movement).

- Rounding of the lumbar spine, most commonly associated with a free weight bent over row, places the low back at a heightened risk of injury (ensure spinal erectors and anterior core muscles are contracted to maintain a strong and neutral posture/spinal alignment).

Modification:

- The width of one's grip can modify the extent to which back musculature is recruited.
- Supinating the hands will increase the activity of the biceps brachii, while pronating will decrease the activation of the biceps brachii.
- Note: It is more important to find a grip that works and feels most comfortable for you as opposed to constantly switching your grip to slightly manipulate muscular recruitment.



Bicep Curl

Agonist muscles include the biceps brachii. Various muscles of the forearm act as synergist muscles for the movement. Stabilizer muscles will vary based on whether the movement is done seated, with a machine or using free weights. As the instability of the movement increases (free weights being the most unstable and machines being the most stable), more stabilizer muscles will be recruited. Common stabilizer muscles will include the erector spinae group, deltoids, and back musculature.



Photo by Andres Ayrton, Pexels License

Form and movement:

- Movement begins with the hands placed on the external load (bar, dumbbells, machine handles) with the elbow joints fully extended.
- The movement is initiated by the biceps brachii contracting to flex the elbow joint and move the external load towards the shoulder region.
- Once the concentric portion of the movement is complete, the biceps brachii controls the weight back to the starting point of the movement using eccentric contractions.

Common mistakes (and how to avoid them):

- Swaying/swinging the upper body to create momentum in order to move more weight (to best isolate the contraction of the biceps brachii and minimize injury risk, one should brace/contract their erector spinae group and anterior core musculature to maintain an upright and neutral spine).

Modification:

- Supinating the hands will increase the activity of the biceps brachii.
- A neutral grip will increase the activity of the forearm muscles and the brachialis muscle.
- Pronating the hands will decrease the activity of the biceps brachii and increase the activity of the forearm muscles.



Tricep Extension

Agonist muscles include the Triceps Brachii. Various muscles of the forearm act as synergist muscles for the movement. Stabilizer muscles will vary based on whether the movement is done seated, with a machine or using free weights. As the instability of the movement increases (free weights being the most unstable and machines being the most stable), more stabilizer muscles will be recruited. Common stabilizer muscles will include the erector spinae group, deltoids, and back musculature.



Photo by Ivan Radic, CC BY 2.0

Form and movement:

- Movement begins with the hands placed on the external load (bar, dumbbells, machine handles) with the elbow joints fully flexed.
- The movement is initiated by the triceps brachii contracting to extend the elbow joint and move the external load towards the abdominal/pelvic region.
- Once the concentric portion of the movement is complete, the triceps brachii controls the weight back to the starting point of the movement using eccentric contractions.

Common mistakes (and how to avoid them):

- Rounding the shoulders and upper back to move them over the external load in order to achieve more recruitment of the pectoralis major and deltoid muscles in order to lift more weight (to best isolate the contraction of the triceps brachii and minimize injury risk, one should brace/contract their erector spinae group and anterior core musculature to maintain an upright and neutral spine).

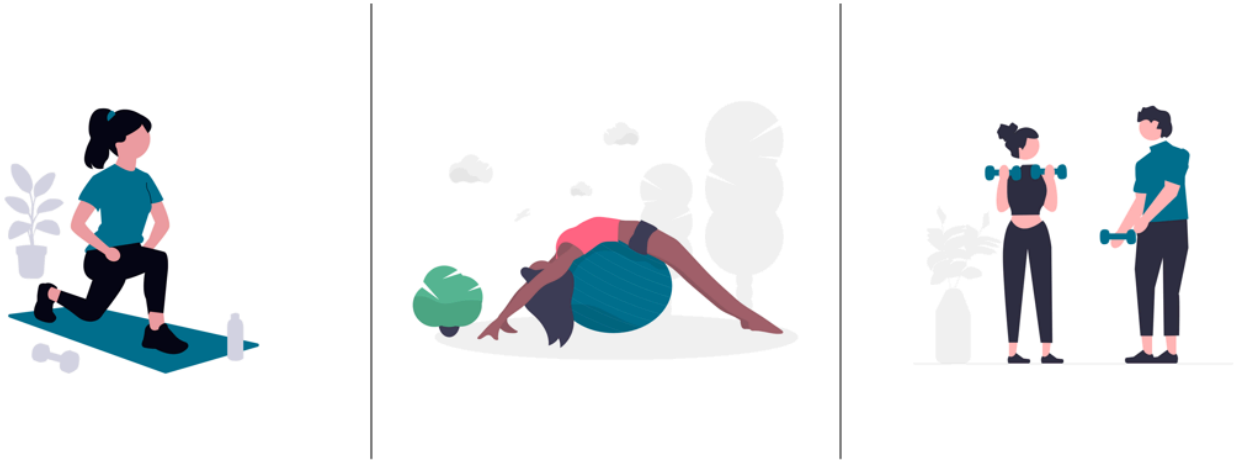
Modification:

- Performing an overhead triceps extension will increase the activation and emphasis on the long head (the largest head) of the triceps brachii by placing it in a stretched position throughout the range of motion.



8.4 RESISTANCE TRAINING PROGRAMS

Training Splits



“Morning Workout”, “Stability ball” and “Personal Trainer” by Undraw, Undraw License

Training splits refer to how an athlete, weightlifter, or casual gym-goer schedules and programs their strength training sessions throughout the week. Splits are typically manipulated based on one’s experience, goals, and the time they can allocate towards strength training on a weekly basis. A few popular workout splits are included below:

Full-body Split

- A full-body split includes training all major muscle groups in each session.
- Typically used by those who are new to resistance training or those with limited time.
- This split most typically involves three full-body workouts per week and is effective in balancing training frequency for each muscle group with adequate rest (i.e., at least one day between full-body training sessions).

Upper/Lower Split

- An upper/lower split includes transitioning between upper and lower body-focused workouts each session.

- This split most typically involves four workouts per week (two upper and two lower), and although muscle groups are not being utilized as frequently on a weekly basis when compared to the full body split, the increase in volume on their respective days may be preferable.
- This split is also effective in balancing training frequency for each muscle group with adequate rest (i.e., three to four days between upper body sessions and three to four days between lower body sessions).

Push, Pull, and Legs Split

- A push, pull, legs split includes transitioning between upper body pushing (movements focusing on the pectoralis major, anterior deltoids, and triceps brachii), upper body pulling (movements focusing on the back musculature, posterior deltoids, and biceps brachii), and lower body focused workouts each session.
- This split most typically involves six workouts per week (two push, two pull, and two legs), and although muscle groups are not being utilized as frequently on a weekly basis when compared to the full body split, the increase in volume on their respective days may be preferable.
- This split is also effective in balancing training frequency for each muscle group with adequate rest (i.e., four days between pushing, pulling, and leg sessions). However, the overall stimulus and systemic training volume may be too much for some.
- This split is often employed by those who enjoy being in the gym nearly every day.

Additional resources on splits include:

- Split Workout Schedule: What to Know and Examples
- What are Workout Splits? Top 3 Most Effective Routines

Workout Schedules

Workout structures refer to how workouts (and even sets within a given workout) are executed.

Manipulating workout structure can alter fatigue levels, energy systems being used, intensity, duration, and many other key variables. A few common workout structures are highlighted below:

Straight/Regular Sets

- Movements are conducted for a given number of repetitions for a given number of sets with a given rest time between sets.
- Example: 4 sets of 8 repetitions with 2 minutes of rest between each set.

Supersets

- Performing a set of two different exercises back-to-back with no designated rest time between.
- Supersets can be performed by the same muscle group (this will create large amounts of volume and fatigue) or antagonistic muscle groups (both groups will be well-rested, and this can be used to save time and increase cardiorespiratory output during a workout).

Drop Sets

- One large set that includes dropping or decreasing the weight 1 to 3 times with little to no rest between weight reductions.
- Example: 6 repetitions are executed, the weight is dropped by 10 to 30%, eight more repetitions are executed, the weight is dropped by another 10-30%, and seven more repetitions are executed.
- This structure maximizes volume and fatigue within a short period of time. If large, heavy movements are being executed, ensure repetitions are stopped and weight is reduced when form starts to break down, as injury incidence increases as one approaches muscular failure.

Additional resources on sets include:

- Straight vs. Ascending Sets: Weighing the Advantages and Disadvantages
- What is a Weighlifting Superset?
- What is a Drop Set? Benefits and How to Use Them.

HIIT (High Intensity Interval Training)

- Includes repeated short bursts of high-intensity aerobic exercise separated by a programmed rest period.
- **HIIT** condenses the timeline of an individual's overall expenditure and often prioritizes intensity and repetitions at the expense of weighted movements and muscular overload.
- Typical HIIT workouts include Tabata, EMOM, AMRAP, and various circuit training.

Additional resources on HIIT include:

- HIIT (High-Intensity Interval Training)

8.5 CHAPTER SUMMARY

Key Takeaways

- **Muscular Strength vs. Endurance:** Muscular strength focuses on generating maximal force for short periods (1–5 reps at 80–100% 1RM), while muscular endurance involves sustaining lower force over longer periods (15+ reps at <60% 1RM). Strength relies on anaerobic energy systems and fast-twitch fibres; endurance uses aerobic systems and slow-twitch fibres.
- **Proper Form and Core Engagement:** Across all upper body exercises—such as planks, push-ups, chest presses, rows, pull-ups, shoulder presses, bicep curls, and tricep extensions—maintaining a neutral spine, engaging the core, and moving with control are essential for safety, efficiency, and maximizing muscle recruitment.
- **Exercise Modifications and Variations:** Exercises can be scaled up or down by adjusting leverage (e.g., knee vs. toe push-ups), grip (e.g., supinated for bicep focus), equipment (e.g., dumbbells vs. resistance bands), and movement angle (e.g., incline bench). These variations allow for personalization and progression.
- **Training Splits Tailored to Goals and Experience:** Common resistance training splits include:
 - Full Body: Ideal for beginners or those with limited time (3x/week).
 - Upper/Lower: 4 sessions/week alternating focus.
 - Push/Pull/Legs: 6 sessions/week targeting movement patterns; better suited for advanced lifters.
- **Workout Structures to Maximize Performance:** Structuring workouts in

various formats—such as straight sets, supersets, drop sets, or HIIT—can influence intensity, fatigue, rest periods, and training focus. Supersets and HIIT enhance efficiency and cardio output; drop sets increase hypertrophy through high fatigue.

- **Integration of Theory and Practice:** This chapter blends theoretical concepts with hands-on instruction, encouraging readers to apply knowledge during physical activity. Emphasis is placed on learning by doing and adjusting routines to improve both strength and endurance while minimizing injury risk.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into key takeaways.

Key Terms

- **Aerobic Energy System:** Energy production using oxygen, used during prolonged, moderate-intensity activity.
- **Agonist Muscle:** The primary muscle responsible for movement in a particular exercise.
- **Anaerobic Energy System:** Energy production without oxygen, used for short bursts of high-intensity effort.
- **Concentric Contraction:** Muscle shortening during contraction, e.g., lifting the weight in a bicep curl.
- **Drop Set:** A training method where the weight is reduced mid-set to continue performing reps beyond fatigue.
- **Eccentric Contraction:** Muscle lengthening during contraction, e.g., lowering the weight in a bicep curl.

- **Fast-Twitch (Type II) Muscle Fibres:** Muscle fibres that contract quickly and powerfully but fatigue rapidly; primarily used in strength and power activities.
 - **HIIT (High-Intensity Interval Training):** A cardiovascular training technique involving short bursts of intense activity followed by rest.
 - **Isometric Contraction:** Muscle contraction without movement, such as holding a plank.
 - **Muscular Strength:** The ability to produce maximal force over a short period (typically 1–5 repetitions at high intensity).
 - **Muscular Endurance:** The ability to sustain submaximal force production over an extended period (15+ repetitions at low intensity).
 - **Muscular Hypertrophy:** An increase in muscle size, often occurring in the 6–14 rep range depending on training variables.
 - **Neutral Spine:** A position where the spine maintains its natural curvature, critical for safe exercise execution.
 - **1RM (One Repetition Maximum):** The maximum amount of weight a person can lift for one repetition of a given exercise.
 - **Repetitions in Reserve (RIR):** A measure of effort, indicating how many more reps you could perform before reaching muscular failure.
 - **Scapular Plane:** A plane of motion between the frontal and sagittal planes where shoulder movement is typically safest and strongest.
 - **Slow-Twitch (Type I) Muscle Fibres:** Muscle fibres that contract more slowly and are fatigue-resistant; primarily used in endurance activities.
 - **Stabilizer Muscle:** A muscle that supports the body or a limb during movement but isn't the primary mover.
 - **Superset:** Performing two exercises back-to-back without rest, either targeting the same or opposing muscle groups.
 - **Synergist Muscle:** A muscle that assists the agonist in performing a movement.
 - **Training Split:** A method of dividing workout sessions throughout the week (e.g., full body, upper/lower, push/pull/legs).
 - **Workout Structure:** The format or method used within a workout (e.g., straight sets, supersets, drop sets, HIIT).
-

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

8.6 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. What is the primary difference between muscular strength and muscular endurance?

- Strength involves more repetitions; endurance involves more weight
- Strength involves fast-twitch fibres; endurance involves slow-twitch fibres
- Strength uses aerobic systems; endurance uses anaerobic systems
- Endurance improves neuromuscular efficiency; strength improves metabolic activity

2. Which of the following best describes a correct plank position?

- Back arched, elbows extended, neck relaxed
- Head flexed forward, hands wide, body sagging
- Neutral spine, forearms under shoulders, controlled isometric hold
- Lower back rounded, glutes tight, shoulders elevated

3. In the push-up exercise, which of the following is considered a common mistake?

- Keeping the elbows at a 45° angle
- Contracting the abdominal muscles
- Letting the midsection sag toward the floor
- Placing hands directly under the shoulders

4. Which training split is most recommended for beginners or those with limited time?

- Push, Pull, Legs

- Upper/Lower
- Full Body
- Isolation

5. Which workout structure involves reducing weight across multiple sets with little to no rest?

- Super Sets
- Drop Sets
- Straight Sets
- HIIT

6. During a pull-down or pull-up, which muscle is the primary agonist?

- Pectoralis Major
- Deltoids
- Biceps Brachii
- Latissimus Dorsi

7. What is one benefit of performing supersets with antagonistic muscle groups?

- It increases rest time between sets
- It lowers overall workout volume
- It saves time and increases cardiorespiratory output
- It reduces fatigue in both muscle groups

Correct Answers:

1. Strength involves fast-twitch fibres; endurance involves slow-twitch fibres
2. Neutral spine, forearms under shoulders, controlled isometric hold
3. Letting the midsection sag toward the floor
4. Full Body
5. Drop Sets

6. Latissimus Dorsi
7. It saves time and increases cardiorespiratory output

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 9: LOWER BODY EXERCISES

Chapter Overview

9.0 Learning Objectives

9.1 Balance

9.2 Breathing & Control

9.3 Basic Lower Body Exercises: Free Body

9.4 Basic Lower Body Exercises: Machine-Based

9.5 Isolated vs Compound Movements

9.6 Exercise Modifications

9.7 Chapter Summary & Key Terms

9.8 Knowledge Check

9.0 LEARNING OBJECTIVES

Learning Objectives

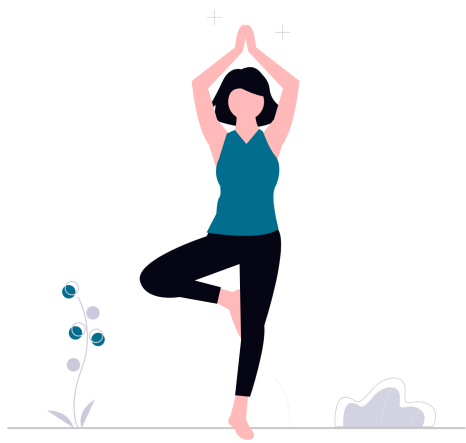
At the end of this chapter, you will be able to:

- Explain the role balance plays in physical activity engagement.
- Explain the three systems which allow us to maintain balance.
- Describe why controlled breathing is necessary for physical activity and provide examples of how breathing patterns may differ between activity types.
- Identify basic lower body exercises; describe how they should be performed; and how they can be modified.
- Differentiate between and describe the rationale for choosing isolated and compound exercises.

Similar to Chapter 8, this chapter should also be used as a practical guide. The information that is shared, as well as how it is shared, encourages readers to learn by doing. This chapter covers lower body exercises and the remaining key components of exercise that were not already covered. However, keep in mind that the key components discussed are related to upper body exercises as well, such as form and workout structures, which are crucial to safe and effective exercise.

9.1 BALANCE

Balance is a foundational component of physical activity and exercise that is often overlooked. In the context of human movement, balance is closely linked to stability; however, they do describe different concepts. Balance refers to the ability to maintain your **Center of Mass (COM)** over your base of support (BOS), whether you are stationary or moving. Whereas stability is the ability to resist movement and maintain control of a joint or body section.



“Yoga” by Undraw, Undraw License

How is your balance? Has your balance changed over time? Or changed after an injury? Why do you think that is? Well, within the body, our ability to balance is dependent on three systems that work together to help us maintain balance and stability: **the visual, vestibular, and proprioceptive systems**. When these systems work together seamlessly, there are no issues. However, if one or more systems are not working adequately or at all, it can impact the entire system, leading to balance deficits and risk of instability. Because these systems like to work together in harmony, when one or more systems are not functioning adequately, or at all, the other systems may work harder to compensate.

- **The Visual System** consists of our eyes, optic nerves, and the visual cortex in the brain. It provides us with information about our environment, therefore helping us to understand where we are in space, what surrounds us, and whether we are stationary or the environment is moving. Ways in which this system could impair our balance are through blurred vision, poor depth perception, low light conditions or a complete lack of information (e.g., eyes are closed or not fully functional).
- **The Vestibular System** consists of inner ear structures, specifically our semicircular canals, otolith organs, vestibular nerve, brainstem, and cerebellum. It detects head movement, orientation, and acceleration, which helps us maintain posture and visual stability. If the vestibular system is impaired, you may feel dizzy, disoriented, or off-balance, even if your COM is within the bounds of your BOS.
- **The Proprioceptive System** consists of muscles, joints, tendons and skin, which include sensory receptors that communicate with the brain and spinal cord via the peripheral nerves. It allows us to sense our body position, movement and pressure when stationary or moving. Without our proprioceptive sense, it is possible that you become clumsy because you aren’t receiving sensory feedback from parts of

the body.

Try This – Challenge Your Balance!

Proceed through the following steps to test your balance and find out if your balance systems are working well together, or which systems are impacting your balance most.

1. Grab a partner to ensure safety during this exercise.
2. Print/use the chart below to record your data.
3. Conduct a balance test by recording how long you can balance for each of the stance guidelines below.

After you’ve completed each balance condition, compare your balance time. Notice any trends or changes in your ability to maintain balance as each of our key balance-aiding systems is isolated and challenged.

Hint: Use a mat with a cushion or a rolled-up towel as an “unstable surface.”

Action	Flat surface/eyes open	Flat surface/eyes closed	Unstable surface/eyes open	Unstable surface/eyes closed
With shoes stand up with two feet together				
With shoes stand with one foot				
Without shoes stand with one foot				

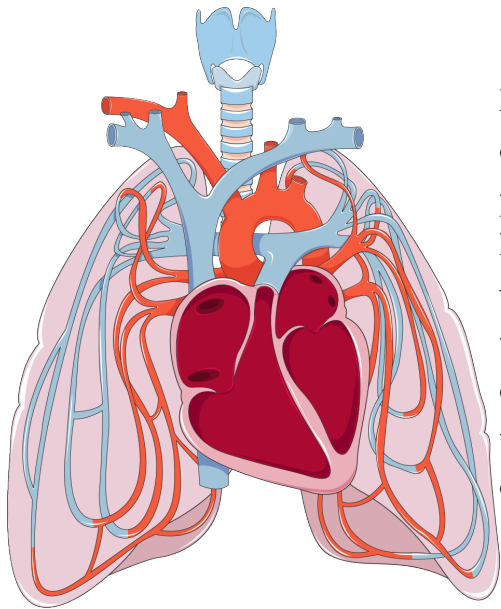
Image Description

A table with 5 columns and 3 rows. The title for the columns are Action, Flat surface/

eyes open, Flat surface/eyes close, Unstable surface/eyes open and Unstable surface/eyes closed. The rows under Action are “With shoes stand up with two feet together”, “With shoes stand with one foot”, and “Without shoes stand with one foot”.

[Challenge Your Balance: Print Version \[PDF\]](#)

9.2 BREATHING AND CONTROL



Why Breathing Matters

Breathing is necessary for human survival because of the uptake of oxygen (O_2) and the exhalation of carbon dioxide (CO_2). During physical activity, however, breathing also influences many aspects and limitations of our performance. By breathing and taking in oxygen via your lungs, the body can deliver oxygen to working muscles through the bloodstream, which aids the production of ATP. In doing so, this helps regulate the body's heart rate (BPM) and energy use. Additionally, breathing can help to provide core stability and calm the nervous system during intense physical activity.

"Cardiovascular system – Pulmonary circulation — Smart-Servier" by Laboratoires Servier, CC BY-SA 3.0



Video: How Exercise Affects the Brain

Video: "How do lungs work? – Emma Bryce" by TED-Ed [3:22] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

How to Breathe During Physical Activity

As a bodily function, breathing is essential to our survival; however, throughout the day, our breathing changes based on the body's demand. At rest, our breath is typically slow and rhythmic, providing enough oxygen to support basic function. During physical activity, the body requires more oxygen and produces more carbon dioxide, which needs to be exhaled. When physical activity begins, the respiratory system adjusts to the change in demand by increasing breath rate alongside heart rate to match energy demands.

Despite the body being able to adjust to changes in demand automatically, conscious control of breathing can further support performance and efficiency during physical activity. By intentionally regulating breath rate and depth, oxygen delivery and energy expenditure can be optimized. Additionally, precise control of breath can also improve endurance and provide core stability.

Breath Control Patterns During Physical Activity

Endurance Activity



Example: long-distance running, swimming or bicycling

Breath Pattern: slow, deep, and rhythmic (often in patterns like 2:2 steps per inhale and exhale)

Purpose: Maintains consistent oxygen intake over time, regulates heart rate and utilizes longer-lasting energy systems (e.g., ETC), which substantially delays the onset of fatigue

“20180924 UCI Road World Championships Innsbruck Women Juniors ITT Tetyana Yaschenko (UKR) DSC 7564” by Granada, CC BY-SA 4.0

Mixed/Interval Activity



Example: HIIT or circuit training

Breath Pattern: Quick, shallow during intense periods of work; deeper, slower breaths during rest intervals

Purpose: Support rapid energy production and recovery of energy systems during rest

Photo by Pixabay, Pexels License

Explosive Activity (Brief)



Example: Power lifting, sprinting, or shot put

Breath Pattern: Breath-holding technique during max exertion, followed by a forceful exhale through the mouth

Purpose: Increase intra-abdominal pressure for core stability during max exertion

"2018-10-07 Weightlifting Girls' 44 kg at 2018 Summer Youth Olympics (Martin Rulsch) 82" by Martin Rulsch, CC BY-SA 4.0

Repetition/Set-based Activity



Photo by Ivan Samkov, Pexels License

Example: Strength training using bodyweight, free weights, or machines

Breath Pattern: Inhale during the easier portion of the movement and exhale during the hard, or more effortful portion (i.e., when you are most exerting yourself)

Purpose: Increase **intra-abdominal pressure** for core stability, regulate oxygen intake, and help to prevent potential dizziness or spikes in blood pressure

9.3 BASIC LOWER BODY EXERCISES: FREE BODY

The following section will demonstrate several basic lower-body exercises and discuss related information, including, but not limited to, the purpose of the exercise, proper form, common mistakes, and **modifications**. When performing any of the following exercises, the following guidelines will help improve efficiency and reduce the risk of injury:

- Always maintain a **neutral spine** from the crown of your head to the base of your tailbone:
 - The head should never be flexed forward or extended backward
 - Shoulders should never be rounded or retracted up
 - The lumbar region should never be rounded or jut out
- All movement should be conducted in a controlled manner: While some activity specifically uses fast or jerky movement, basic physical activity is most beneficial when completed in a smooth, consistent manner.
- Core or abdominal engagement should always be maintained to protect the spine and trunk muscles from injury.

Each of the discussed exercises has several variations that involve a change in body positioning and/or weight or resistance bands that can be used to increase the difficulty of the exercise when placed in front, behind or on the body using a variety of equipment (e.g., barbell, dumbbell, kettlebell, or resistance band).

Squat



Types of squats and various foot positions, “Woman Lifting Barbell” (top left) by Li Sun, Pexels License, “Man Using Yellow Kettlebell” (bottom left) by Ketut Subiyanto, Pexels License, “Woman in Activewear Exercising” (right) by RDNE Stock project, Pexels License

Purpose: Challenges the quadricep group, glute group, hamstring group, and core muscles.

Form and movement pattern:

- Movement begins in anatomical position and mimics sitting in a chair, then standing back up by bending at the knees and a slight forward hinge at the hip.
- Knees should not extend far past the toes.
- Motion should exhibit similar speed during both downward and upward phases, with a brief pause in between (during the seated portion).

Common mistakes (and how to avoid them):

- Shifting COM too far forward, resulting in knees extending far past the toes and/or heels lifting off the ground during knee flexion (shift weight backward to correct positioning).
- Knees collapsing inward (engage glute muscles to stabilize the knee).

- Shallow depth, if not being used as a modification, could indicate a lack of flexibility and impaired ROM (engage in hip, knee, and ankle mobility exercises and stretching to increase joint ROM and muscle length).

Modification & equipment:

- Foot placement can be used to emphasize certain muscles over others (e.g., a wider stance will activate the glute muscles more than a narrow stance could).
- Weight or resistance bands can be used to increase difficulty. (e.g., A barbell positioned behind the head, across the shoulders; a kettlebell held in front of the chest or between the legs; or a resistance band looped under the feet and over a hand or shoulder are all examples of ways a weighted squat can vary).



Lunge

Purpose: Challenges the quadricep group, glute group, hamstring group, and calf muscles (e.g., gastrocnemius & soleus) unilaterally.

Form and movement pattern:

- Movement begins in anatomical position, stepping one leg forward while keeping the torso upright and the opposing leg extended backward.
- The front knee should bend to approximately 90 degrees, with the back knee moving toward the floor.
- The front thigh should be parallel with the floor, and the knee should not extend past the toes.
- After lowering and a brief pause, alternate legs by stepping the front leg back to anatomical position or stepping the back leg forward to anatomical position.



Photo by Anna Shvets, Pexels License

Common mistakes (and how to avoid them):

- Shifting weight too far toward will place additional strain on the front knee (attempt equal weight distribution between front and back legs by engaging the front leg quadricep group and back leg glute group).
- Lacking core engagement can contribute to instability (engage core by imagining the belly button is being pulled towards the spine)
- Shallow depth, if not being used as a modification, could indicate a lack of flexibility and impaired ROM (engage in hip, knee, and ankle mobility exercises and stretching to increase joint ROM and muscle length).

Modification & equipment:

- Foot placement can be used to emphasize certain muscles over others and complete movement in various ROM pathways (e.g., the leading leg can be stepped forward, to the side, diagonally, etc.).
- Weight or resistance bands can be used to increase difficulty. (e.g., dumbbells held in either hand, a medicine ball held in front of the chest, or a barbell held behind the head, across the shoulders, are all examples of ways a weighted lunge can vary).

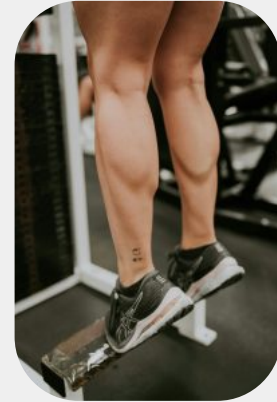


Calf Raise

Purpose: Challenges the gastrocnemius, soleus, tibialis posterior, and smaller muscles in the foot and stabilizing muscles around the ankle joint

Form and movement pattern:

- Movement being in anatomical position, with feet hip-width apart and weight evenly distributed between both feet.
- Feet should plantar flex, allowing the heels and body to rise a few inches from the ground while keeping the knees extended but not locked (e.g., extended with a slight bend to engage stabilizing muscles)
- Movement should be vertical, and ankles should remain aligned, without rolling in or out
- The upward and downward phases should be slow and controlled, with a brief pause at the top to engage the calf muscles fully before returning the heels to the ground



“Calves of Woman at Gym” by Amar Preciadodf, Pexels License

Common mistakes (and how to avoid them):

- Shifting weight too far toward or backward can easily move the body's COM outside of the BOS and cause instability (if attempting for the first time or problems with balance are present, use a wall or bar as a balance aid)
- Bouncing up and down too quickly reduces muscle activation and can increase strain on applicable joints (align the upward and downward phases with slow and controlled breaths in and out)
- Inadequate ROM (e.g., not lifting heels high enough or not lowering them all the

way down) can be improved through ankle and calf mobility exercises and stretching to increase ROM and muscle length

Modification & equipment:

- Foot placement or feet used can be used to emphasize specific muscles over others (e.g., staggered foot placement, elevated heel placement, or using one foot at a time)
- Weight or resistance bands can be used to increase difficulty. (e.g., Dumbbells held in either hand, a sandbag over a shoulder, or a medicine ball held in front of the chest are all examples of ways a weighted calf raise can vary)



9.4 BASIC LOWER BODY EXERCISES: MACHINE-BASED

Leg Press

Purpose: Challenges the quadriceps group, the gluteus group, the hamstrings group, and the calves.

Form and movement pattern:



- Movement begins seated with the back and head supported by the backrest, with the feet placed hip-to-shoulder-width apart on the platform.
- Extend legs to press the platform away from the body, avoiding full extension of the knees.
- Lower the platform by bending at the knees and hips until the thighs are approximately 90 degrees to the lower leg.
- Extension and flexion of the knees and hips should be slow and controlled, with a brief pause at the bottom of the movement.

“Leg Press” by GeorgeStepanek, CC BY-SA 3.0

Common mistakes (and how to avoid them):

- Letting knees collapse in or outward reduces proper alignment (keep knees in line with toes; a ball or foam roller squeezed in between the knees can help).
- Allowing the lower back or hips to lift off the backrest can increase strain on the lumbar spine (keep core engaged and avoid excessive knee flexion).

- Locking the knees at full extension places the load on the joint rather than the working muscle (maintain a slight bend at the top of the movement).

Modification & equipment:

- Foot placement can alter muscle emphasis (e.g., higher foot placement engages the glute and hamstring groups more, whereas lower placement emphasizes the quadricep group).
- Single-leg press can address muscle imbalance.
- Weight and ROM can be adjusted to suit individual needs.



Leg Extension

Purpose: Isolates and challenges the quadricep group (i.e., rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius).

Form and movement pattern:

- Movement begins seated in the machine with the back against the backrest, knees aligned with the machine's pivot point, and shins under the padded bar.
- Extend knees by contracting the quadriceps group to lift the padded bar upward.
- At the top, pause briefly before slowly lowering the bar back to the starting position.
- Knees should not lock at the top; movement should remain smooth and controlled in both directions.



“Leg Extension Machine Exercise” by GeorgeStepanek, CC BY-SA 3.0

Common mistakes (and how to avoid them):

- Lifting the hips off the seat pad can increase stress on the lumbar spine (adjust the backrest to the preferred depth and angle, and engage the core).
- Using momentum or swinging, the legs lead to reduced muscle activation (movement should be slow and controlled).
- Locking knees at full extension can strain the joint (stop just short of full extension or ‘lockout’).
- Letting the toes point downward, or plantar flex, disengages some of the quadriceps group muscles (keep toes in a neutral or slightly dorsiflexed position).

Modification & equipment:

- Adjust seat height, angle, and position of all pads (back and/or legs) to assure proper support.
- Weight and ROM can be altered to suit individual needs.



Hamstring Curl

Purpose: Challenges the quadriceps group, the gluteus group, the hamstrings group, and the calves.

Form and movement pattern:

- Movement begins with the thighs firmly supported and the padded bar resting just above the heels (seated or prone).
- Flex the knees by drawing the heels toward the glute group, engaging the hamstrings group.
- Pause briefly at the end of the curl before slowly returning to the starting position.
- Keep hips and upper body stable to prevent compensatory movement.



“Lying Leg Curl Machine Exercise” by GeorgeStepanek, CC BY-SA 3.0

Common mistakes (and how to avoid them):

- Arching the back or lifting the hips (especially in a prone position) reduces isolation (maintain contact with the pad and engage the core).
- Using momentum or jerking the weight reduced muscle activation and control (slow down both phases of the movement).
- Incomplete ROM reduces effectiveness (ensure the full flexion and extension without locking of the knee joint).

Modification & equipment:

- Adjust the seat height, angle or pads for individual preference.
- Machines may offer seated, prone, or standing variations; choose the one that best suits your control level.
- Single-leg hamstring curls can help address muscle imbalances.

- Resistance bands or ankle weights can also be used to mimic the movement.



9.5 ISOLATED VS COMPOUND MOVEMENTS

Whether beginning to exercise or trying to refresh your current routine, it's important to understand the difference between **isolated** and **compound exercises**, and how each can serve different goals related to function, performance and physique.

Isolated Exercises



“Woman doing sit-ups” by Johnathan Borba, Pexels License

Isolated exercises utilize a single joint and muscle group and are useful when the goal is to target a specific muscle or muscle group. Reasons for isolated training may include rehabilitating a previous injury, correcting muscular imbalances, increasing strength and performance, or increasing size for aesthetic reasons.

Text Description

Some examples of isolated exercises and their corresponding muscle groups are the quadricep group used during _____, the bicep brachii used during a _____ and the abdominals used during a _____.

Possible answers:

- bicep curl
 - leg extensions
 - sit-up
-

Correct Answers:

Some examples of isolated exercises and their corresponding muscle groups are the quadricep group used during ***leg extensions***, the bicep brachii used during a ***bicep curl*** and the abdominals used during a ***sit-up***.

Compound Exercises



Photo by Miriam Alonso, Pexels License

Compound exercises utilize multiple muscles and muscle groups and are especially useful for developing overall strength, coordination, and functional movement patterns. Common reasons for choosing them include improving athletic performance, burning calories, supporting everyday movement, and building balanced muscle development in various areas of the body.

Text Description

Some examples of compound exercises and their corresponding muscle groups are the quadricep, hamstring, and glute group used during a _____, the tricep brachii and deltoid used during a _____ and the abdominal, back and glute group used during a _____.

Possible answers:

- lunge
 - shoulder press
 - plank
-

Correct Answers:

Some examples of compound exercises and their corresponding muscle groups are the quadricep, hamstring, and glute group used during a ***lunge***, the tricep brachii and deltoid used during a ***shoulder press*** and the abdominal, back and glute group used during a ***plank***.

9.6 EXERCISE MODIFICATIONS

Within this chapter, six basic exercises were described and discussed with the intent to serve as a practical guide. While some modification examples were given relative to the six basic exercises covered, this section will provide a further understanding of why exercises may need to be modified and how to do so.

There are many reasons why an exercise may need to be modified, and recognizing these needs is crucial to safe and effective physical activity. Individuals come into exercise with a wide range of abilities, fitness levels, injuries, health conditions, goals, and resources. Modifications can help accommodate temporary and long-term factors that may impact an individual's ability to function within or perform a physical movement.

Short- vs Long-term Modifications

Modifications can help accommodate short-term conditions or circumstances such as muscle soreness from a previous workout or exercise; fatigue from overactivity, inadequate fuelling, health conditions or dehydration; or recovery from an injury, either recent or accommodating a healed injury. Modifications can also help with long-term conditions or circumstances such as joint limitations that restrict ROM or lead to pain or discomfort; balance challenges, which could increase fall risk; or chronic conditions that impact body systems such as skeletal muscle or metabolism.

Bust a Myth – Modifications Make Exercise Easier

Modifications are deviations from an exercise's basic form or starting point that are sometimes viewed as a weakness or doing something 'less than'. However, this view of modifications is inaccurate. Modifying an exercise is a smart, individualized approach that allows someone to move within their body's bounds, reducing the risk of injury and contributing to a healthier lifestyle. Everybody is built slightly different and therefore may require different exercises to match an individual's current stretch, mobility and coordination, and achieve an effective workout.

Consider these two individuals wanting to improve their leg strength...



Avatar by Undraw,
Undraw License

Sean is a hockey player in his off-season, and he would like to focus on strengthening his legs. He chooses a front squat with a weighted barbell to emphasize his quadriceps muscles. Because Sean wants to increase strength, he typically completes 3-4 sets or six repetitions of a moderate to heavy weight.



Avatar by Undraw,
Undraw License

Terra is recovering from a knee injury and would like to return to her hiking group. She chooses a body weight squat over a bench to focus on joint ROM and equal weight distribution between her legs. Because she wants to return to her hiking group, which typically goes on 2-3 hour hikes, she decides to focus on endurance by completing 3-4 sets of 15-20 repetitions. Additionally, to increase her inner knee stability, Terra squeezes a small ball between her knees during the up- and downward phases of the squat.

Both individuals see improvement in their abilities and progress toward their goals. Without the modifications (e.g., changes in weight, ROM, repetitions, additional equipment, etc.), each individual would have been unable to achieve their goal.

Activity: Fourteen Ways to Modify an Exercise

Read each modification and click on the card to see an example of how it can be implemented during exercise.

Text Description

Weight: Increase or decrease the weight being pulled or pushed.

Example: Increase the weight of dumbbells when three sets of 10 shoulder presses start to feel easier.

Resistance: Change the amount of resistance to make the exercise more or less challenging.

Example: Use a Heavier resistance band for glute bridges to increase difficulty, or remove a band to decrease it.

ROM: Adjust how far a joint moves during an exercise.

Example: Perform a half squat instead of a full squat if there is knee pain or limited mobility.

Time Elapsed: Modify the duration of effort or work, specifically in timed intervals or isometric holds.

Example: Hold a plank for 20 seconds instead of 30 if attempting to build up endurance and or manage muscle fatigue.

Contact Points: Change how many parts of the body are touching the supporting surface to alter stability.

Example: A basic plank (hands and feet touching the ground) can be modified by allowing the knee to act as a third contact point or removing a foot to remove a contact point.

Body Positioning: Shift the orientation of the body to reduce or increase the load

Example: A seated lateral shoulder raise is an alternative to a standing version.

Equipment: Switch or add equipment to change load, stability, or focus.

Example: Swap dumbbells for resistance bands during a bicep curl for a different resistance feel.

Number of Repetitions or Sets: Change how many times the exercise is performed to adjust the volume of work.

Example: Perform two sets of 8 lunges instead of 3 sets of 12 repetitions to reduce total workload.

Speed or Tempo: Slow down or speed up the movement to affect intensity, control or focus.

Example: Sit up and down slowly (3 seconds up; 3 seconds down) to emphasize muscular control during a sit-up.

Use of Support or Aid: Incorporate external support to assist with balance, control and posture.

Example: Use a chair or strap during squats to improve stability and confidence during movement.

Impact on the Body: Modify whether the movement is high or low impact to suit joint health and comfort level.

Example: Swap jumping jacks for body weight sumo squats with an arm lift or run on a treadmill, as opposed to a concrete sidewalk.

Amount of Rest: Change the length or rest between sets and exercises to manage recovery or increase challenge.

Example: Rest for 60 seconds instead of 30 between sets to allow better recovery during strength training.

The Movement Pattern or Starting Position: Simplify or alter a movement path or where it begins to meet individual needs.

Example: Perform a wall push-up instead of a floor push-up to reduce load and improve form.

Intended Goal: Modify the exercise to better match the purpose (e.g., strength balance, endurance, etc.)

Example: Use lighter weights and higher reps to target muscular endurance instead of strength.

As stated previously, everybody is different. Even when people share the same goal, whether it's building strength, improving balance or increasing mobility, the path they take to get there may look completely different from someone else. Exercise modifications are not a sign of limitation, but a powerful way to tailor movement to meet individual needs, abilities, and preferences. By honouring your body and adjusting exercises as needed, you can move safely, confidently, and effectively toward your personal goals. There is no one-size-fits-all approach to fitness, and modifications are what make progress possible.

9.7 CHAPTER SUMMARY

Key Takeaways

- **Balance and Its Systems:** Balance is essential in physical activity, relying on the visual, vestibular, and proprioceptive systems. These systems work together to maintain posture, stability, and control during movement. Impairment in any one can lead to instability and increased injury risk.
- **Controlled Breathing and Activity Type:** Breathing patterns affect performance, energy use, and stability. Patterns differ by activity: rhythmic for endurance, controlled bursts for interval or explosive exercises, and paced inhaling/exhaling for strength training. Conscious breath control enhances performance and prevents fatigue or dizziness.
- **Form, Safety, and Lower Body Exercises:** Proper technique is critical for exercises like squats, lunges, and calf raises. Maintaining a neutral spine, engaging core muscles, and moving with control are emphasized to avoid injury. Variations and equipment like resistance bands or weights help adapt exercises to different fitness levels.
- **Machine-Based Exercises:** Exercises like the leg press, leg extension, and hamstring curl isolate or challenge key muscle groups safely. Proper seat adjustments, range of motion control, and avoiding momentum ensure effective and injury-free training.
- **Isolated vs. Compound Movements:** Isolated exercises target a single muscle group (e.g., leg extensions), useful for rehab or precision training. Compound exercises (e.g., squats, lunges) engage multiple joints and muscles, which is ideal for building overall strength, function, and coordination.

- **Modifications for Individual Needs:** Modifications are essential, not a weakness. They help accommodate injuries, mobility limits, or different goals (e.g., strength vs. endurance). Exercises can be modified by adjusting weight, ROM, tempo, contact points, equipment, or posture to ensure safe, effective workouts for every individual.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>
 Prompt: Please summarize the following content into six key takeaways.

Key Terms

- **Balance:** The ability to maintain your centre of mass (COM) over your base of support (BOS), whether stationary or in motion.
- **Centre of Mass (COM):** The point in the body where mass is evenly distributed; maintaining it over the base of support is essential for balance.
- **Compound Exercise:** Engages multiple joints and muscle groups (e.g., squats); ideal for strength, coordination, and functional movement.
- **Contact Points:** Parts of the body in contact with a supporting surface; changing them can affect balance and difficulty.
- **Endurance Activity:** Long-duration activities like running or swimming require sustained oxygen intake and a regulated heart rate.
- **Explosive Activity:** Short, high-intensity movements like sprinting or powerlifting that may use breath-holding techniques for core stability.
- **Intra-abdominal Pressure:** Pressure generated in the abdominal cavity during exertion; helps stabilize the core during heavy lifts.

- **Isolated Exercise:** Targets a single joint and muscle group (e.g., leg extension); useful for rehab, imbalances, or aesthetic goals.
- **Neutral Spine:** A spinal position maintaining the natural curves of the neck, upper back, and lower back; critical for safe exercise form.
- **Modification:** Any change to an exercise's form, range, intensity, or equipment to match individual ability, goal, or condition.
- **Proprioceptive System:** This includes muscles, joints, tendons, and skin; it provides sensory feedback to the brain about body position and movement.
- **Repetition/Set-Based Activity:** Strength training exercises with defined reps and sets; breathing patterns are regulated based on movement difficulty.
- **Stability:** The ability to resist movement and maintain control of a joint or body section.
- **Tempo:** The speed at which an exercise is performed, impacting intensity and control.
- **Vestibular System:** Located in the inner ear; detects head movement, orientation, and acceleration to help maintain posture and visual stability.
- **Visual System:** Composed of the eyes, optic nerves, and visual cortex; helps interpret surroundings and body position in space.

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>
Prompt: List the key terms and their definitions in the content provided.

9.8 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. Which of the following systems is NOT involved in maintaining balance?
 - Visual system
 - Respiratory system
 - Vestibular system
 - Proprioceptive system
2. What is the primary purpose of a lunge exercise?
 - To isolate the quadriceps only
 - To challenge upper-body coordination
 - To work the lower body muscles unilaterally
 - To increase ankle flexibility
3. During explosive activities like sprinting or powerlifting, what breathing technique is commonly used?
 - Shallow breathing throughout
 - Holding the breath during exertion, then forcefully exhaling
 - Deep breathing through the nose only
 - Fast breathing throughout the movement
4. What is the difference between isolated and compound exercises?

- Isolated exercises use multiple joints, compound uses one
 - Compound exercises focus only on aesthetics
 - Isolated exercises target one muscle group, and compound exercises involve several
 - There is no difference
5. What is a key form cue for performing a proper squat?
- Allowing the knees to move far past the toes
 - Keeping the shoulders raised and tight
 - Maintaining a neutral spine and controlled motion
 - Holding your breath throughout the movement
6. Which modification would help improve balance for someone performing calf raises?
- Using a resistance band
 - Performing the movement faster
 - Holding onto a wall or stable surface
 - Jumping instead of lifting heels
7. What does ROM stand for, and why is it important in exercise?
- Rest over muscle; important for recovery
 - Range of motion; it ensures safe and effective joint movement
 - Rate of movement; it improves cardiovascular health
 - Resistance of muscle; it builds muscle tension
-

Correct Answers:

1. Respiratory system
2. To work the lower body muscles unilaterally
3. Holding the breath during exertion, then forcefully exhaling

4. Isolated exercises target one muscle group, and compound exercises involve several
5. Maintaining a neutral spine and controlled motion
6. Holding onto a wall or stable surface
7. Range of motion ensures safe and effective joint movement

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 10: EXERCISE NEUROSCIENCE

Chapter Overview

10.0 Learning Objectives

10.1 Brain Fog

10.2 The Brain and Body Interaction

10.3 Human Movement and the Brain

10.4 Exercise and Mental Health

10.5 Exercise-Induced Cognitive Function Enhancement

10.6 Physical Activity and Brain Health

10.7 Chapter Summary

10.8 Knowledge Check

10.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Recognize the connection between the brain and body as it pertains to movement.
- Identify the four lobes of the brain and their function(s).
- Explain the frontal lobe's role in initiating movement.
- Discuss the direct and indirect effects of exercise on brain health, psychological well-being, and mental health.
- Describe exercise-induced increases in cognitive function.

10.1 BRAIN FOG



Picture This...



Image by Kaboompics.com, Pexels License

You finally drag yourself to the hospital for a check-up that your parents used to routinely schedule for you, but that you are now solely responsible for scheduling and attending. You get called into the doctor's office and get checked in by a nurse who informs you that the doctor will be by shortly. After waiting for a few minutes, which seems like an eternity, the Doctor finally arrives and asks you, "How has everything been feeling lately?".

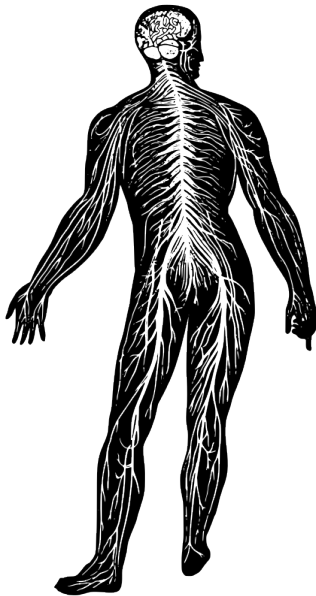
Surprisingly, this question catches you off guard, and you quickly think to yourself, "That's a really good question. How have I been feeling lately?" You think back to all of the times you had difficulty concentrating for extended periods of time, all the times you had been scraping your memory in search of information that you just couldn't quite seem to retrieve, all the times where it felt like your mental health was continuously declining, all the time you spent scrolling on Instagram reels or TikTok before snapping out of your "doom scroll" to think "what did I just spend the last hour and half of my time watching?" You quickly stop reflecting to answer the doctor's question with the quick, safe, and artificial response of "everything has been feeling pretty good, doc."

In this chapter, we explore the critical and holistic relationship between the brain and body. We discuss how

the brain works to facilitate movement of the body and, conversely, how the body can work to enhance overall brain function and health.

10.2 THE BRAIN AND BODY INTERACTION

Neuroscience, a field first formally recognized in the 1960s, refers to the study of the nervous system (the brain, spinal cord, and nerves).



“Nervous System” by
j4p4n , Public Domain

The study of neuroscience has taught us that the brain is an extremely complicated organ with trillions of connections throughout the body. Some of those connections communicate information down towards the body, such as signals that allow us to produce movement by instructing our skeletal muscles (Chapter 5.3) to contract in a sequential and coordinated manner. Other connections ascend into the brain, conveying all sorts of information from the world around us, such as how hot or cold our environment is, the sounds we hear at any given time, how hungry we are, and where body parts are in relation to others.

The nervous system conveys all this information using a combination of electrical and chemical signals that allow us to function by receiving information and facilitating activities of daily living.

Exercise Neuroscience is a much newer field of study that is growing quite rapidly. It is a subdomain of neuroscience that seeks to further understand how movement, physical activity, and exercise work to influence the nervous system

and vice versa.



Video: How Exercise Affects the Brain

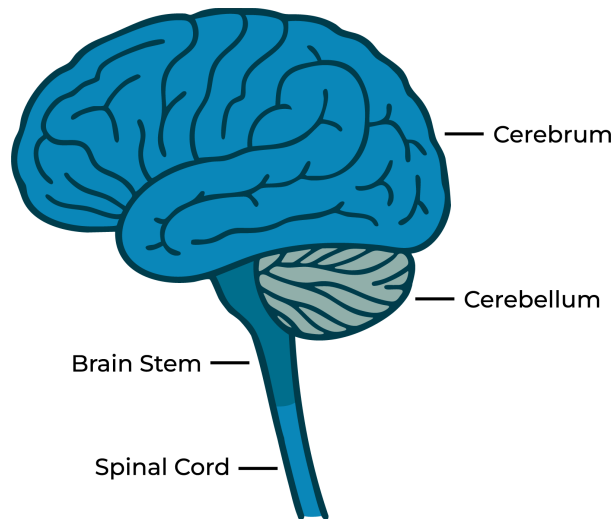
“How exercise affects the brain” by BYU Life Sciences [1:29] is licensed under the Standard Video License. Transcript and closed captions available on YouTube.

In this video, the narrator explains how exercise affects the brain by highlighting three key mechanisms of action:

1. Exercise increases blood flow to the brain, allowing for increased nutrients and metabolites to enter the brain and fulfill its metabolic demands.
2. Exercise aids in memory storage and formation by increasing certain molecules within the brain (i.e., **Brain-Derived Neurotrophic Factor or BDNF**).
3. Exercise mitigates stress by stimulating **endorphin** release and lowering cortisol levels.

“What is Neuroscience?” from Principles of Biology by Catherine Creech is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

10.3 HUMAN MOVEMENT AND THE BRAIN



“Parts of the Brain” by Koen Liddiard, CC BY-NC-SA 4.0

The brain is made up of these four key components – cerebrum, brain stem, cerebellum and spinal cord.

The Cerebrum

The **cerebrum** is the largest part of the brain and is responsible for higher-order functions such as cognition, sensory processing, memory, and motor function, to highlight a few. The cerebrum can be further subdivided into four lobes, each with a wide array of functions.

Activity

Click on each icon to learn more about each lobe in the cerebrum and its functions.

Text Description

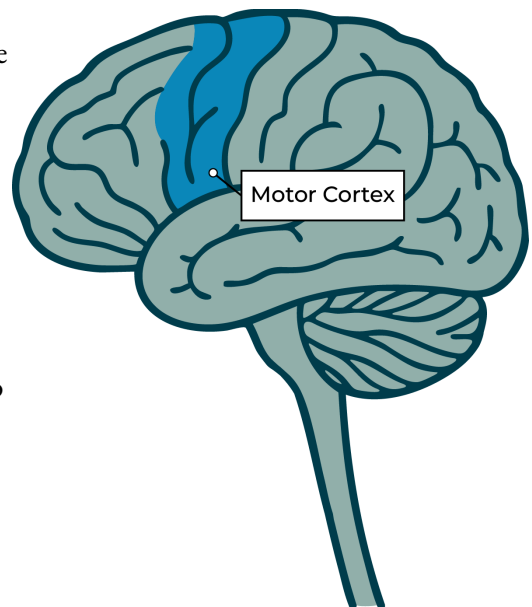
Image of the brain with hotspots containing the four lobes and their definitions:

1. Frontal: Cognition and motor function.
2. Parietal: Processing of sensory information.
3. Occipital: Processing of visual information.
4. Temporal: Memory formation and the processing of auditory information.

The Frontal Lobe

Of these four lobes, human movement is initiated within the **frontal lobe** in a region called the **primary motor cortex**. For the body to ultimately produce voluntary movement, electrical signals need to be sent from the primary motor cortex to the skeletal muscle fibres by travelling down the following pathway:

1. The primary motor cortex initiates a signal or command that will eventually elicit movement.
2. This command then moves down through the brain and into the spinal cord.
3. The signal continues to descend through the spinal cord towards its destination.
4. Nerves then transmit this signal to the muscle fibres, instructing them to contract or relax.
5. The culmination of these sequential contractions ultimately produces movement.





Video: Two-Minute Neuroscience

Video: “2-Minute Neuroscience: Motor Cortex” by Neuroscientifically Challenged [1:47] is licensed under the Standard YouTube License. *Transcript and closed captions available on YouTube.*

“What is Neuroscience?” from Principles of Biology by Catherine Creech is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

10.4 EXERCISE AND MENTAL HEALTH

Exercise and physical activity can have a positive effect on aspects of **mental health** and psychological well-being, such as depression, anxiety, and overall mood. Here, we will examine the effects that exercise can have on different aspects of our mental health.

We will begin by defining the term mental health.

The World Health Organization (WHO) defines mental health as “a state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn and work well, and contribute to their community” (WHO, 2022, para 1).

Using this definition, there are two possible ways in which exercise can benefit mental health (OE Commons, n.d.):

1. Exercise can prevent or reduce the extent of mental illnesses such as depression and/or anxiety, allowing us to achieve a state of mental well-being.
2. Exercise can enhance mood and reduce stress levels, thus allowing us to tackle daily challenges in a more positive, optimistic, and constructive way.



“Sportive woman with bicycle” by Andrea Piacquadio, Pexels License

The Impacts of Exercise

According to The Open University (n.d.), exercise enhances mood, reduces stress levels, and ultimately increases mental health in the following ways:

- **Cortisol:** **Cortisol** is also known as the stress hormone because its levels increase in response to stress. Although strenuous physical activity can acutely increase cortisol levels, long-term exercise regimens can aid in the chronic regulation and response of cortisol levels.

- Endorphins: **Endorphins** are chemicals produced in the brain during painful or stressful activities. Given that exercise is a painful stressor (to varying degrees based on intensity), there is a large endorphin release both during and after exercise. Endorphins bind to centers in the nervous system that decrease pain and increase feelings of reward (Cleveland Clinic, 2022).
- Thoughts, emotions, and confidence: The feelings of reward and decreased stress that we feel as a by-product of the exercise-induced endorphin release and cortisol response have been continuously shown to increase mood, confidence, and positive emotion.
- Socialization: Physical activity and exercise can indirectly increase mental health by promoting socialization. Whether engaging in team sports, fitness classes, or just being surrounded by like-minded individuals, physical activity can assist in deriving the many health benefits associated with increased levels of socialization.
- Sleep: Physical activity and exercise can also indirectly increase mental health by increasing the quantity and quality of sleep. Exercise has been continuously shown to increase sleep quality and quantity as well as expedite sleep onset (the time it takes to fall asleep). Additionally, sleep quality has been highly correlated with mental health outcomes both acutely and chronically.



“Morning Workout” by
Undraw, Undraw
License

Fitness Fact

Although exercise has been shown to improve sleep, high-intensity exercise close to your bedtime can be detrimental to sleep health. For best results, look to schedule high-intensity exercise earlier in the day and opt for a light to moderate intensity if exercising within a few hours of your desired bedtime.

10.5 EXERCISE-INDUCED COGNITIVE FUNCTION ENHANCEMENT

The Six Domains of Cognitive Function

Cognitive function is composed of six domains associated with the acquisition, comprehension, and utilization of information. Click on each card to learn more about each domain.

Text Description

Front of Card

1. Attention
2. Executive function
3. Learning and memory
4. Language
5. Motor control
6. Social cognition

Back of Card:

1. Our ability to choose what we are going to focus on (whether laser-focused on a single task or dispersing our attentional resources in an attempt to multitask).
2. Higher-order cognitive processes are associated with decision-making, planning, and organization.
3. Our ability to record, store, and retrieve information.
4. Our ability to communicate
5. Our ability to coordinate bodily movements in response to our goals and

environment.

6. Our ability to effectively store and use information in social settings and interactions.

How Exercises Increase Cognitive Function



“Woman in pink shirt” by Nathan Cowley, Pexels License

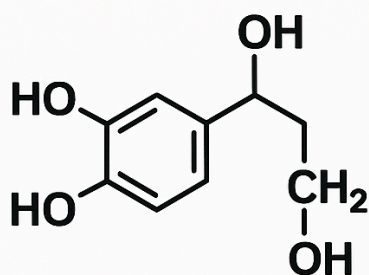
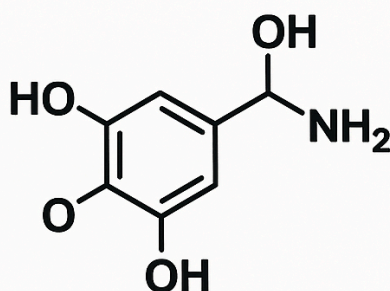
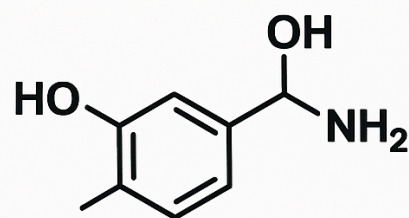
Exercise can be used as a tool that not only enhances our physical function, but it has been proven that both resistance and cardiorespiratory exercise can increase cognitive function (Etnier et al., 2020). The following mechanisms contribute to exercise-induced cognitive enhancement:

Increased Blood Flow to the Brain

When exercising, the body undergoes increases in both heart rate and blood pressure, which work to increase blood flow to the working musculature and the rest of the body. This increase in overall blood flow also increases the amount of blood being delivered to the brain, which in turn has been shown to increase cognition and brain function (Guiney et al., 2015).

Increase in Catecholamines and Brain-Derived Neurotrophic Factor (BDNF)

Exercise increases the release of catecholamines (adrenaline, noradrenaline, and dopamine) and BDNF, which have also been shown to increase cognitive function (McMorris, 2021).

**adrenaline****noradrenaline****dopamine**

The chemical structures of three catecholamines: adrenaline, noradrenaline, and dopamine. These neurotransmitters are released during exercise and are linked to improved cognitive function. “Chemical bonds” combination of Noradrenalin by 28Smiles, CC BY-SA 4.0, Epinephrine by Roland1952, Public Domain, Dopamine by OldakQuill, CC BY-SA 3.0

Fitness Fact

Increases in cognitive function can be detected after just one workout.

10.6 PHYSICAL ACTIVITY AND NERVOUS SYSTEM HEALTH

We are constantly told that exercise and regular movement are beneficial for many facets of our physical health, whether it’s the cardiovascular system, the respiratory system, the musculoskeletal system, or the metabolic system, to name a few. However, it is less often that we are informed of the benefits of exercise on our nervous system.

Brain health is a comprehensive metric that encompasses many of the attributes previously discussed in this chapter (**cognitive function**, mental health, and neural efficiency). The chart below highlights the benefits of **acute** and **chronic** exercise on brain health.

Acute Exercise (Single Bout)	Chronic Exercise (Repeated Exercise for Weeks)
↑ focus increases ↑ positive emotion increases ↑ memory increases ↓ negative emotion decreases	↓ anxiety symptoms decrease ↓ depressive symptoms decrease ↓ risk of neurodegenerative disease decreases ↑ long-term memory increases

Exercise and Neurodegenerative Disease



“Personal holding a stress ball” by Mattias Zomer, Pexels License.

The health of the nervous system is also extremely important in its association with longevity. In his bestselling book *Outlive: The Science & Art of Longevity*, Dr. Peter Attia highlights **neurodegenerative disease** (i.e., Alzheimer’s and Parkinson’s) as one of four main chronic diseases that significantly contribute to mortality and health (Attia & Gifford, 2023). Neurodegenerative diseases are those associated with an overall decline in cognitive ability (see Chapter 10.5 for factors of cognition) that is severe enough to impact daily living. This can lead to confusion, mood swings, and difficulty with daily tasks such as speaking,

movement, and facial recognition. Here is a comparison between Alzheimer’s and Parkinson’s and how they impact the body:

Alzheimer’s	Parkinson’s
“Alzheimer’s disease is the most common form of dementia, a brain disorder that slowly destroys a person’s memory and thinking skills. It is characterized by a loss of cognitive functioning – thinking, remembering, and reasoning – and behavioural abilities to such an extent that it interferes with a person’s daily life and activities” (National Institute on Aging, 2021, para 1).	“Parkinson’s disease is a progressive movement disorder of the nervous system. It causes nerve cells in parts of the brain to weaken, become damaged, and die, leading to symptoms that include problems with movement, tremor, stiffness, and impaired balance. As symptoms progress, people with Parkinson’s disease (PD) may have difficulty walking, talking, or completing other simple tasks” (National Institute of Neurological Disorders and Stroke, 2023, para 1).

Chronic, long-term exercise interventions (resistance and cardiorespiratory) have been continuously shown to not only reduce the incidence of Alzheimer’s and Parkinson’s, but also to aid in the management of neurodegenerative disease due to their benefits within the nervous system and with overall motor function (Paillard et al., 2015).

“The Four Horsemen of Chronic Disease” from Principles of Biology by Catherine Creech is licensed under a Creative Commons Attribution 4.0 International License, except where otherwise noted.

10.7 CHAPTER SUMMARY

Key Takeaways

- **The Brain-Body Connection Enables and Benefits from Movement:** The nervous system coordinates body movement through electrical and chemical signals. The frontal lobe, especially the primary motor cortex, initiates voluntary movement. In turn, physical activity enhances brain health and function.
 - **Exercise Improves Mental Health and Emotional Well-being:** Regular physical activity helps reduce anxiety and depression, enhances mood, regulates cortisol (stress hormone), boosts endorphins, and improves sleep and social interaction—all of which contribute to better mental health.
 - **Physical Activity Enhances Cognitive Function:** Both acute and chronic exercise improve cognitive domains such as attention, executive function, memory, and motor control by increasing blood flow, stimulating BDNF, and elevating catecholamines like dopamine and adrenaline.
 - **The Brain Has Four Lobes with Distinct Functions:** The frontal, parietal, temporal, and occipital lobes control different aspects of movement, sensation, memory, and perception. Understanding these functions is key to recognizing how exercise can stimulate specific brain regions.
 - **Exercise Promotes Brain Health and Reduces Risk of Neurodegenerative Disease:** Acute exercise boosts focus, memory, and mood, while long-term exercise reduces symptoms of depression and anxiety, enhances long-term memory, and lowers the risk of Alzheimer's and Parkinson's disease.
-

OpenAI. (May 27th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into five key takeaways.

Key Terms

- **Acute Exercise:** A single bout of physical activity that can have immediate effects on focus, mood, and memory.
- **Adrenaline:** A type of catecholamine hormone released during exercise or stress that increases heart rate and energy availability.
- **Attention:** The ability to selectively focus on specific tasks or stimuli, either narrowly or broadly distributed.
- **Brain-Derived Neurotrophic Factor (BDNF):** A protein that supports the growth, function, and survival of brain cells and is associated with improved learning and memory.
- **Catecholamines:** A group of hormones—including adrenaline, noradrenaline, and dopamine—that are released during stress or exercise and play a role in mood, attention, and cognition.
- **Cerebrum:** The largest part of the brain responsible for higher-order functions such as thinking, memory, sensory processing, and motor control; subdivided into four lobes.
- **Chronic Exercise:** Repeated bouts of physical activity over weeks or months, which lead to long-term benefits for brain and physical health.
- **Cognitive Function:** A set of mental abilities, including attention, memory, language, executive function, and motor control, that allow for information processing and response.
- **Cortisol:** A hormone produced by the adrenal glands in response to stress, often called the “stress hormone”; regulated by regular exercise.

- **Dopamine:** A catecholamine neurotransmitter involved in motivation, reward, and motor function, increased through exercise.
- **Endorphins:** Chemicals produced in the brain during stress or pain that reduce discomfort and increase feelings of pleasure or reward.
- **Executive Function:** High-level cognitive processes such as planning, decision-making, problem-solving, and self-control.
- **Frontal Lobe:** A brain region responsible for motor function, planning, decision-making, and initiating voluntary movement via the primary motor cortex.
- **Language:** The ability to understand and produce spoken or written communication.
- **Learning and Memory:** The process of acquiring, storing, and retrieving information.
- **Mental Health:** According to the WHO, a state of well-being is one in which individuals can cope with daily stresses, work productively, and contribute to their community.
- **Motor Control:** The ability to regulate and coordinate body movements in response to goals and the environment.
- **Neurodegenerative Diseases:** Conditions such as Alzheimer's and Parkinson's are characterized by progressive loss of structure or function of neurons, often leading to impaired movement or cognition.
- **Neuroscience:** The scientific study of the nervous system, including the brain, spinal cord, and peripheral nerves.
- **Noradrenaline:** A catecholamine hormone that helps regulate attention, arousal, and blood pressure, and is increased during exercise.
- **Parietal Lobe:** A region of the brain involved in processing sensory information such as touch, temperature, and spatial awareness.
- **Primary Motor Cortex:** A region in the frontal lobe responsible for initiating voluntary muscle movements.
- **Social Cognition:** The ability to process, store, and apply information about social situations and interactions.
- **Temporal Lobe:** A brain region responsible for processing auditory information and forming memories.

OpenAI. (May 27th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

10.8 KNOWLEDGE CHECK

Knowledge Check Activity

Text Description

1. Drag and Drop Activity
 - Input boxes: Parietal, Frontal, Occipital, and Temporal
 - Draggable items: Processing of visual information, Cognition and motor function, Processing of sensory information, Memory formation and the processing of auditory information
2. What is one direct benefit of exercise on the brain?
 - Reduced appetite
 - Increased blood flow and nutrient delivery
 - Improved bone density
 - Enhanced vision
3. Which of the following best defines mental health, according to the World Health Organization (WHO)?
 - The absence of mental illness
 - A state of well-being that enables people to cope with life's stresses and function well
 - Having no emotional responses
 - Maintaining a daily fitness routine
4. What is Brain-Derived Neurotrophic Factor (BDNF) known to do?

- Improve digestive health
- Increase muscle mass
- Aid memory formation and cognitive function
- Suppress cortisol production

5. What role do endorphins play in mental health during exercise?

- Reduce hydration needs
- Decrease pain and increase feelings of reward
- Stimulate hunger
- Lower oxygen demand in the brain

6. Which of the following is NOT one of the six cognitive domains enhanced by exercise?

- Executive function
- Social cognition
- Bone strength
- Motor control

7. How does chronic exercise impact the risk of neurodegenerative diseases like Alzheimer's and Parkinson's?

- It has no effect
- It increases the risk slightly
- It reduces the risk and supports disease management
- It delays symptoms by only a few hours

Correct Answers:

1. Drag and Drop:

- Parietal: Processing of sensory information
- Frontal: Cognition and motor function

- Occipital: Processing of visual information
 - Temporal: Memory formation and the processing of auditory information
2. Increased blood flow and nutrient delivery
 3. A state of well-being that enables people to cope with life's stresses and function well
 4. Aid memory formation and cognitive function
 5. Decrease pain and increase feelings of reward
 6. Bone strength
 7. It reduces the risk and supports disease management

OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Please create seven multiple-choice questions with answers based on the content shared.

CHAPTER 11: TISSUES, JOINTS, AND MOVEMENT RELATED PATHOLOGIES

Chapter Overview

- 11.0 Learning Objectives
- 11.1 Types of Muscle Tissue
- 11.2 Skeletal Muscle Anatomy
- 11.3 Joints: Synovial
- 11.4 Cartilaginous & Fibrous
- 11.5 Soft Tissue Injuries
- 11.6 Inflammation
- 11.7 Muscular Dysfunction
- 11.8 Common Injuries
- 11.9 Conditions Impacting Movement
- 11.10 Chapter Summary
- 11.11 Knowledge Check

11.0 LEARNING OBJECTIVES

Learning Objectives

At the end of this chapter, you will be able to:

- Differentiate between muscle tissue types.
- Describe skeletal muscle anatomy and explain the function of a sarcomere.
- Outline the role of each joint classification.
- Recall specific soft tissue injuries and describe how they impair movement.
- List the signs of inflammation and understand the relation to movement impairment.
- Describes ways in which muscle dysfunction can impair movement.
- Identify common movement-related pathologies.
- Provide examples of physical activity or sport that common movement-related pathologies are associated with.

11.1 SKELETAL MUSCLE TISSUE

As we learned in Chapter 5, muscle tissue plays a crucial role in supporting our daily life, and it not only helps us move and complete daily tasks, but it also supports life-sustaining functions such as breathing, circulation, and digestion. While skeletal, cardiac, and smooth muscle all work together to support the bodily functions, they differ in structure. Let's explore these differences below.

Skeletal Muscle:

- Striations (banded or striped appearance due to arrangement of contractile proteins) are clearly visible
- Voluntary control through fast contractions
- Primarily used for the movement of the trunk and limbs
- Example: The bicep brachii muscle found in the upper arm

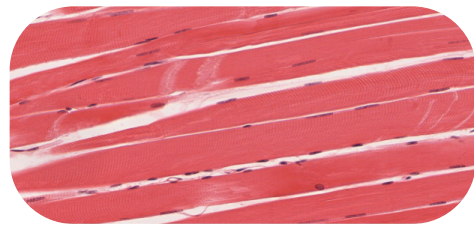


Image by OpenStax College, CC BY 3.0, Modifications: Cropped

Smooth Muscle:

- No striations
- Involuntary control through slow and sustained contractions
- Used for the function of internal organs
- Example: The stomach

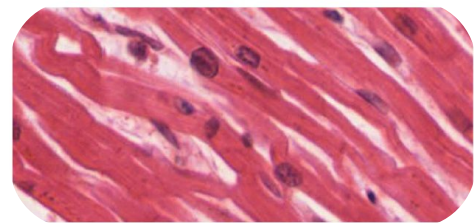


Image by OpenStax College, CC BY 3.0, Modifications: Cropped

Cardiac Muscle:

- Striations present but less distinct
- Involuntary control through rhythmic contractions
- Used to pump blood throughout the body
- Example: The heart

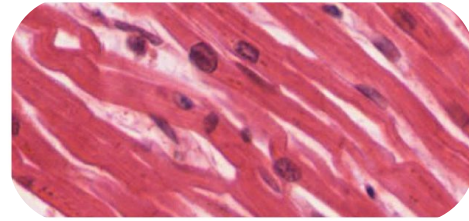


Image by OpenStax College, CC BY 3.0, Modifications: Cropped

Despite their differences, a property common to all three types of muscle is **contractility**, or the ability of a muscle to contract and generate force. While muscle tissue can shorten with contractions, it also displays **extensibility** or the ability to stretch and extend beyond the resting length and **elasticity**, which allows the muscle to recoil back to its resting length. Without such properties, our ability to function normally would be unattainable.

Given the focus of this resource on physical activity and human movement, the primary focus of the following section will be on skeletal muscle, as it plays the central role in producing human movement.

“10.1 Overview of Muscle Tissues” from Anatomy & Physiology by Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, OSU OERU & OpenStax is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License, except where otherwise noted.

11.2 SKELETAL MUSCLE ANATOMY

Located throughout the body, skeletal muscle contractions produce movement that enables us to engage in physical activity and exercise. But how exactly does it do it? To understand how this occurs, you will need a basic knowledge of anatomy and the structure of skeletal muscle.

Anatomy of Skeletal Muscle

Click on each icon to learn more about the different parts that make up skeletal muscle.

Text Description

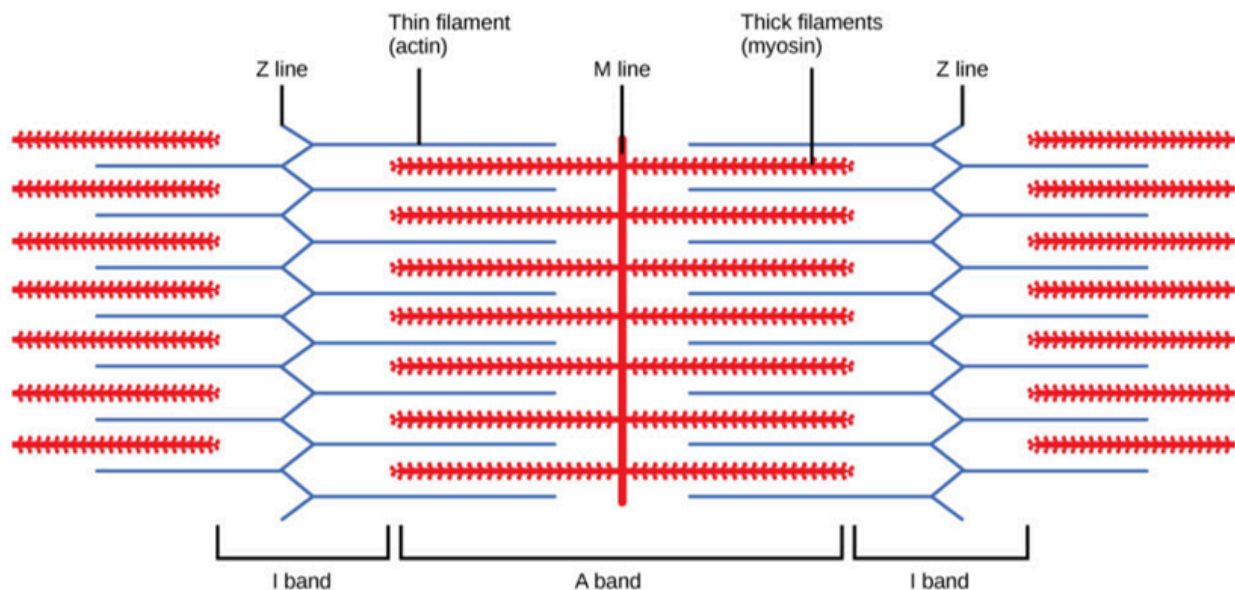
An anatomical diagram of skeletal muscle structure showing the layers from whole muscle to myofibril. The image labels the muscle belly, epimysium, perimysium, endomysium, fascicle, muscle fibre, sarcolemma, and myofibril.

- The Muscle Belly: The outermost layer of connective tissue that surrounds the entire muscle.
- Epimysium: The outermost layer of connective tissue that surrounds the entire muscle.
- Perimysium: The connective tissue layer that surrounds bundles of muscle fibres.
- Fascicle: A bundle of skeletal muscle fibres.
- Endomysium: The thin connective tissue that surrounds each individual muscle fibre.
- The Muscle Fibre: A bundle of myofibrils.
- Sarcolemma: The muscle fibre membrane.
- Myofibrils: Rod-like structures composed of repeating sarcomeres that contain contractile elements.

Sarcomeres & Sliding Filament Theory

The sarcomere is the smallest contractile unit within skeletal muscle and is the reason we are able to shorten and lengthen our muscles. How movement happens is explained through the **Sliding Filament Theory**. But before we dive into how movement happens, we need to understand the components that make it happen. Using the diagram of a sarcomere below, follow along as each component is discussed.

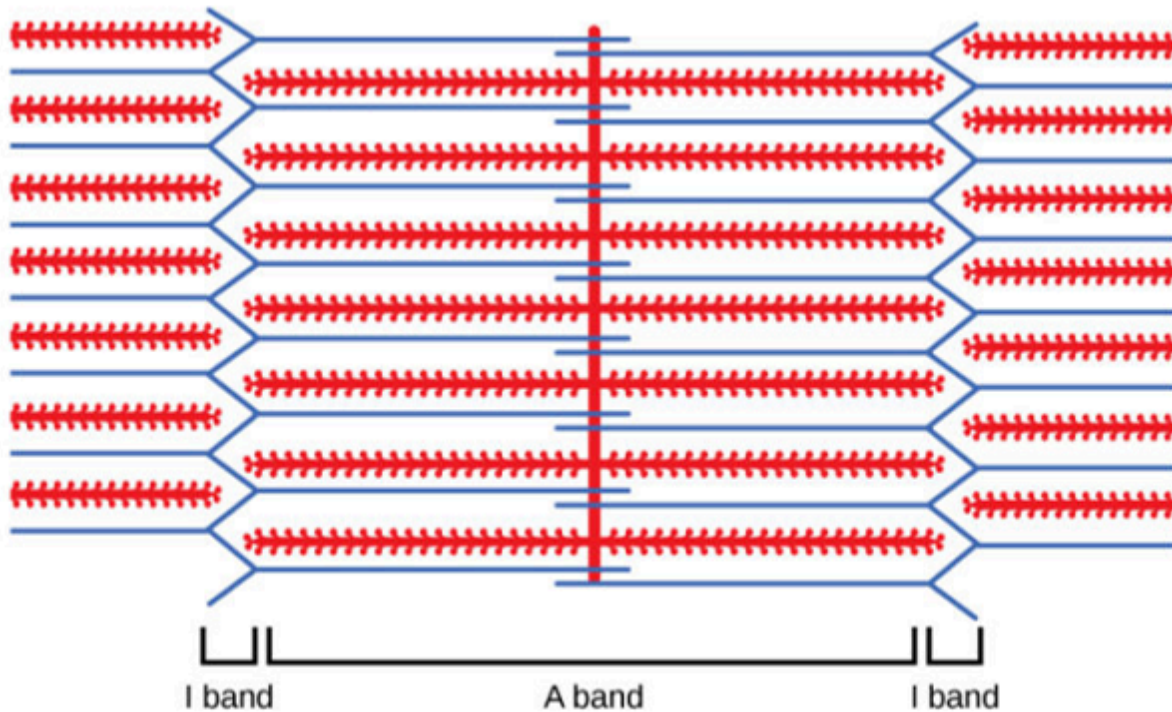
The illustration below is representative of a sarcomere, and therefore a muscle, at resting length. Each sarcomere begins and ends at the Z line, with its center point being the M line located in the middle. Several rows of two types of contractile filaments create the key components of the sarcomere. These are Actin, the thin filament, and Myosin, the thick filament. Both filaments are positioned in a highly organized, alternating structure that enables a sliding interaction.



A sarcomere at rest. The image shows a symmetrical arrangement of thick and thin filaments. Thin actin filaments extend from both Z lines toward the center, overlapping with thick myosin filaments anchored at the M line. The Z lines define the boundaries of one sarcomere. The I bands consist of only thin filaments, while the A band includes the full length of the thick filaments. The central H zone, within the A band, contains only thick filaments and is bisected by the M line. Image by OpenStax, CC BY 4.0 Modified: Cropped out the contraction stage.

Contraction (or lengthening) occurs where the filament position changes, which therefore changes how much they overlap with one another. We measure if a muscle has contracted or lengthened by looking at the I and A bands indicated below. The A band represents the portion of the sarcomere where actin and myosin filaments overlap, while the I band represents where they do not, and only actin is present. When the sarcomere, and therefore the muscle, contracts, the A band increases in size while the I band decreases.

However, when a muscle lengthens and the filaments overlap less, the A band decreases in size while the I band increases.



When a sarcomere contracts, the Z lines move closer together and the I band gets smaller. The A band stays the same width and, at full contraction, the thin filaments overlap. Image by OpenStax, CC BY 4.0 Modified: Cropped out the resting stage.

“10.1 Overview of Muscle Tissues” from *Anatomy & Physiology* by Lindsay M. Biga, Staci Bronson, Sierra Dawson, Amy Harwell, Robin Hopkins, Joel Kaufmann, Mike LeMaster, Philip Matern, Katie Morrison-Graham, Kristen Oja, Devon Quick, Jon Runyeon, OSU OERU & OpenStax is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License, except where otherwise noted.

11.3 JOINTS: SYNOVIAL

While Chapter 4 discusses bones that make up our skeleton, it is not enough to stop there. How our skeleton functions depends not only on the bones (and muscles) that make up the body, but we also need to consider how each component is connected to the others. In addition to 206 bones, our body is held together by approximately 360 joints, connecting those bones together. Not all 360 joints, however, enable movement. Some joints are designed to permit little or even no movement. These joints provide support and even protection.

Consider your skull, for example. The part of your skull that encases the brain is known as cranial bones and provides your brain protection from external impact, and they are joined together through a specific type of joint, which does not allow movement. But what other types of joints are there?

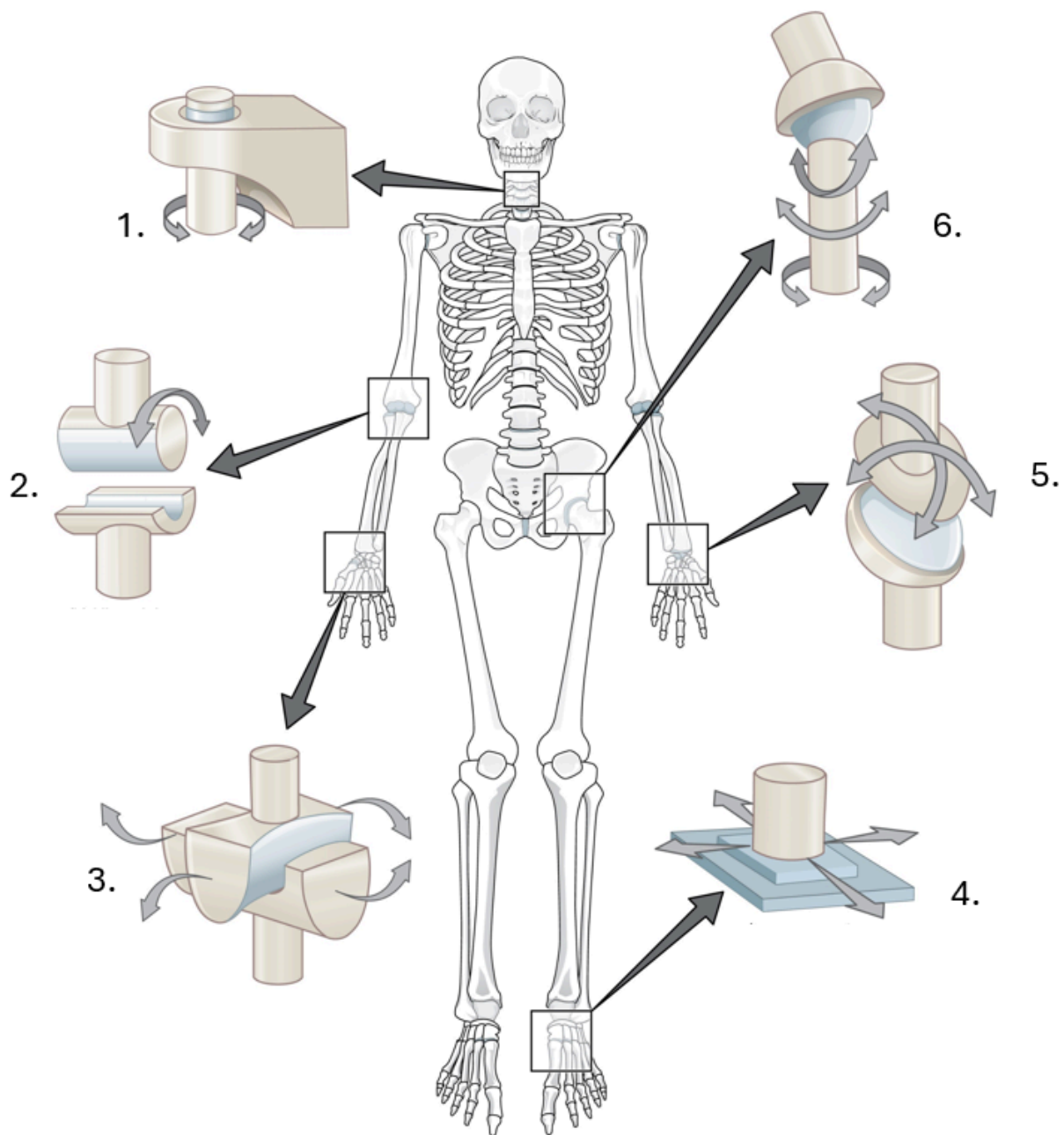
Joint Classification

There are three classifications of joints that exist throughout the body: Synovial, Cartilaginous, and Fibrous. Each classification allows the body the amount of movement it requires: no movement, little or restricted movement, or a wide range of movement. However, the following sections will discuss all three types of joint classifications, with a greater focus on **Synovial Joints** because of their crucial role in movement and physical activity.

Synovial Joints

Synovial joints are the most common type of joint in the body and allow us to move (relatively) freely. Synovial joints exist where two adjacent bones are connected by a joint cavity. The joint cavity houses the ends of bones where articulation needs to occur; synovial fluid, which helps lubricate the joint; and cartilage, which covers the ends of bones to absorb shock and reduce friction. There are six types of synovial joints: the pivot, hinge, condyloid, saddle, plane (or gliding), and ball-and-socket joint.

Joint Name	Permitted Movement	Joint Example(s)
1 Pivot	Rotation of one bone relative to another around a single axis	Atlantoaxial joint (Vertebrae C1-C2), Radioulnar joint
2 Hinge	Flexion and extension	Elbow joint, Knee joint
3 Saddle	Flexion, extension, abduction, adduction and circumduction	Thumb joint (1st Carpometacarpal Joint)
4 Plane	Sliding or gliding motions (limited)	Intercarpal (Wrist) joints, Intertarsal (Foot) joints
5 Condylod (Ellipsoidal) Joint	Flexion, extension, abduction, adduction and circumduction	Wrist Joint (Radiocarpal)
6 Ball-and-socket	Flexion, extension, abduction, adduction, and circumduction	Shoulder joint, Hip joint



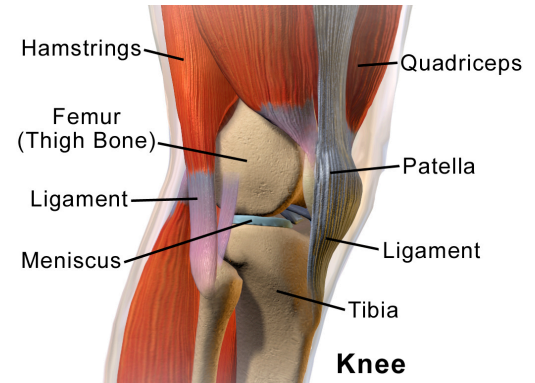
The location and types of synovial joints. Image by OpenStax College, CC BY 3.0. Modifications: Text removed and replaced with numbers.

Image Description

Diagram of the human skeleton with arrows pointing to six types of synovial joints. The pivot joint at the neck allows rotational movement. Hinge joint at the elbow and knee enables bending and straightening. A condyloid joint at the wrist allows movement in two directions. The plane (gliding) joint in the ankle allows sliding movements. The saddle joint at the base of the thumb enables back-and-forth and side-to-side motion. Ball-and-socket joint at the shoulder and hip allows movement in all directions.

The variety of synovial joints in the body allows us to move in diverse ways; however, the joint capsule alone cannot support the movement our bodies demand. Tendons, Ligaments, Menisci, and Bursae all play a role in supporting joint function and movement.

- **Tendons:** The connective tissues which connect bones to muscles and transmit force from muscle to produce movement (e.g., the patellar tendon connects the quadriceps muscle group to the tibia and plays a key role in knee extension).
- **Ligaments:** The connective tissue which connects bone to bone, which works to stabilize joints and limit movement (e.g., your medial cruciate ligament or MCL in your knee, restricts side-to-side movement outside of typical hinge joint flexion and extension).
- **Menisci:** The crescent-shaped pads of fibrocartilage found in certain joints that provide shock absorption and help distribute weight across joint surfaces (e.g. the menisci within the knee joint cushion impact during walking and running).
- **Bursae:** The small, fluid-filled sacs are located between bones and soft tissues that aim to reduce friction and enable smooth, painless movement (e.g., the prepatellar bursa exists in front of the patella, or kneecap, to allow smooth movement of the knee over the knee during movements such as kneeling).



Anatomical image of the human knee showing muscles, bones, and connective tissues. Labels identify the hamstrings and quadriceps muscles, femur (thigh bone), patella (kneecap), tibia, meniscus, and two ligaments connecting the bones."Knee Anatomy" by BruceBlais, CC BY 3.0

Despite the support of these structures, some joints are more susceptible to injury or movement-related issues than others. Conditions that impact movement and injuries that commonly occur because of movement and sport will be discussed later in Chapter 11.9.

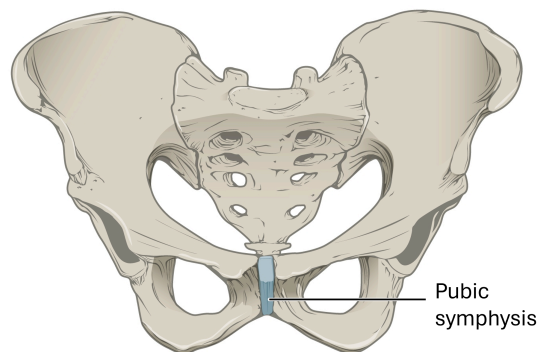
11.4 JOINTS: CARTILAGINOUS AND FIBROUS

Cartilaginous Joints

Unlike synovial joints, which allow and support ample movement, cartilaginous joints are more restrictive. Cartilaginous joints exist where adjacent bones are joined by a firm, but flexible connective tissue known as cartilage. Cartilage provides structural support to our anatomy and helps to absorb shock or force that impacts the body.

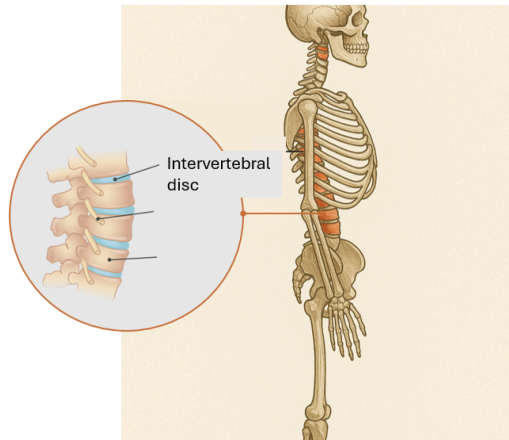
There are two types of cartilaginous joints:

- Sychondrosis Joint: Involves bones joined together by hyaline cartilage (e.g., Epiphyseal or growth plates in long bones of growing children)



Anterior view of the human pelvis highlighting the pubic symphysis, a cartilaginous joint connecting the left and right pubic bones at the front of the pelvic girdle."Cartilaginous joints" by OpenStax, CC BY-SA 3.0

- Symphysis Joint: Involves bones joined together by fibrocartilage (e.g., Intervertebral discs of the spinal cord)



The intervertebral discs of the spinal cord.
"Healthy Spine" by Injury Map, CC BY-SA 4.0
Modified: Added circle and "Skeletal side profile"
image (see source below)

Fibrous Joints

Fibrous joints are made up of adjacent bones directly connected to each other by fibrous connective tissue. In fibrous joints, there is no joint cavity between bones; however, the gap between them can be narrow or wide.

There are three types of fibrous joints:

- A Suture Joint is the narrow fibrous joint found between most bones of the skull, like the cranial bone example discussed earlier.

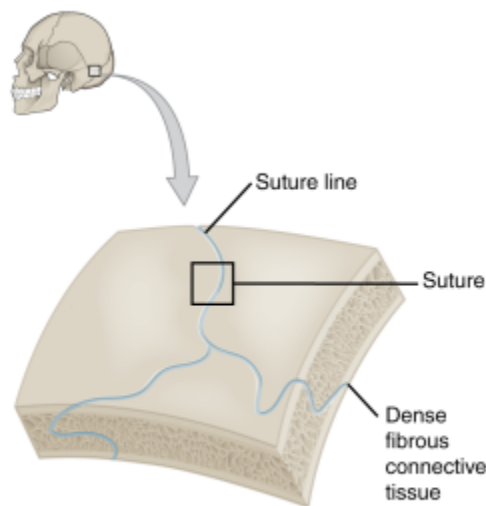


Illustration of a section of the human skull showing a suture joint. A zoomed-in view highlights the suture line where two skull bones meet, connected by dense fibrous connective tissue. "Fibrous Joints" by OpenStax College, CC BY 3.0, Modified: Cropped

- A Syndesmosis Joint is a wider fibrous joint where bones are held together by

a thin band of fibrous connective tissue (e.g., a ligament or interosseous membrane). This type of fibrous joint is found between the shaft regions of the long bones, such as the forearm or lower leg.

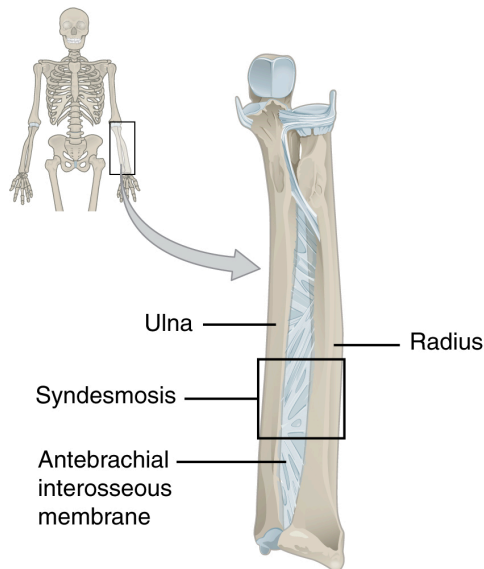


Diagram showing the ulna and radius bones of the forearm with a focus on the syndesmosis joint. The antebrachial interosseous membrane connects the two bones, providing support and stability. "Fibrous Joints" by OpenStax College, CC BY 3.0, Modified: Cropped

- A Gomphosis Joint is the narrow fibrous joint between the roots of a tooth and the bony socket in the jaw into which the tooth fits.

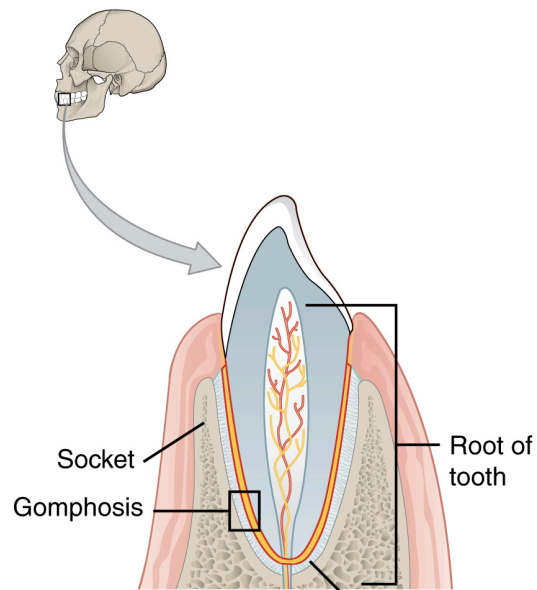


Illustration showing a cross-section of a tooth rooted in the jawbone. Labels identify the root of the tooth, the socket in the jaw, and the gomphosis joint, where the tooth is anchored by fibrous tissue. "Fibrous Joints" by OpenStax College, CC BY 3.0, Modified: Cropped

"Skeletal side profile" Image: OpenAI. (2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat> Prompt: Create a side skeletal profile of the human body. Highlight the intervertebral discs.

11.5 SOFT TISSUE INJURIES

At this point, we know that movement is essential to daily life and can only occur when several bodily components work together in harmony. However, the components that allow our body to move (e.g., muscles, bones, tendons, ligaments, etc.) are vulnerable to a wide range of injuries and disorders that can inhibit movement. Movement-related pathologies refer to injuries and conditions that impair the body's ability to move efficiently. These can arise from physical trauma, overuse, inflammation, degeneration, or structural abnormalities. The following section will explore common movement-related injuries and conditions, some of which are caused by movement or lack of or simply impact the ability to move freely.

Sprain vs Strain

One way injury can inhibit movement is through soft tissue injuries such as sprains and strains. Although they sound quite similar and are often used interchangeably, sprains and strains actually differ in what type of tissue is damaged and, therefore, what therapeutic measures are required.

- **Sprain:** A sprain describes injury to a ligament, the type of tissue that connects bone to bone. Sprains are typically caused by a sudden impact that forces a joint outside of its normal range of motion (ROM). Sprains are most common in ankles, knees, and wrists.
- **Strain:** A strain describes injury to a tendon, the type of tissue that connects bone to muscle, or muscle. Strains are typically caused by overstretching or overusing an area or muscle.

Fitness Fact

Ankle Sprains, sometimes referred to as ‘rolling an ankle’, are quite common because they do not require an individual to be engaged in intense physical activity. Ankle sprains, specifically inversion of the ankle, are most common and can occur simply by taking a misstep while walking. Inversion ankle sprains are more common than eversion because of two reasons:



1. The foot's natural arch already has our weight sitting on the outer or lateral edge of the foot. “Injury” by Undraw, Undraw License
2. The ligament supporting the lateral side of our ankle, the Anterior Talofibular Ligament (ATFL), is quite narrow and therefore most susceptible to injury, in comparison to the Deltoid Ligament, which supports the ankle medially.

Both sprains and strains can occur in varying degrees, known as grades ranging from 1 to 3, where the higher the grade indicates the more severe the injury.

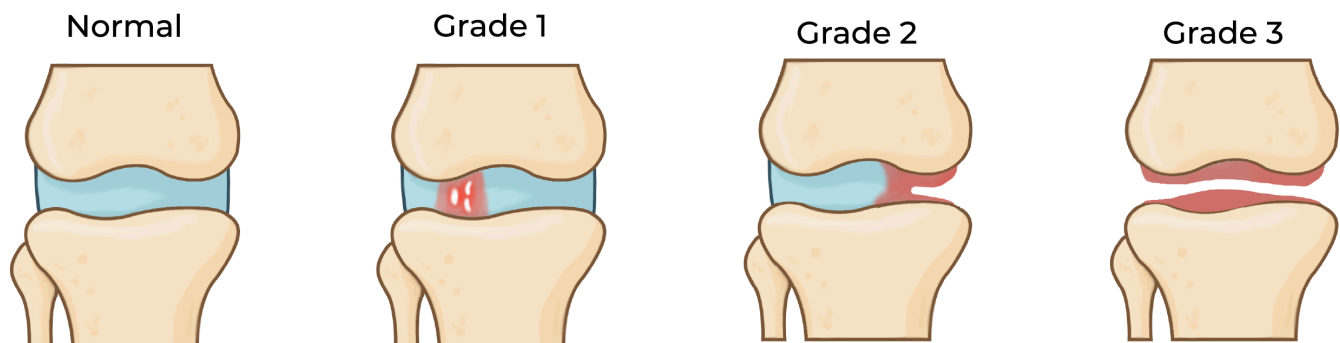


Diagram showing four stages of cartilage health in a joint. The first panel shows a normal joint with smooth cartilage and joint space. Grade 1 shows slight cartilage softening or swelling. Grade 2 shows partial cartilage erosion and thinning. Grade 3 shows severe cartilage loss with exposed bone surfaces and narrowing joint space. “Degrees of strains” by Koen Liddiard, CC BY-NC-SA 4.0

- Grade 1: Describes stretch or small tears in the tissue
- Grade 2: Describes a partial tear of the tissue
- Grade 3: Describes a full or complete tear of the tissue

Dislocations & Subluxations

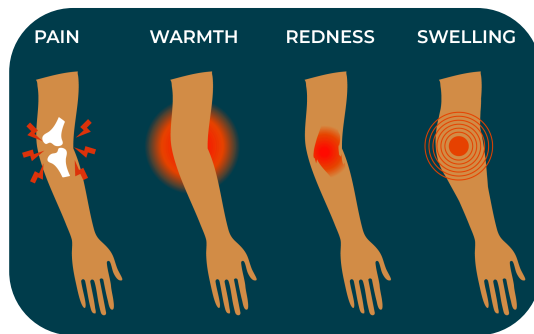


Lateral X-ray of a dislocated right elbow showing misalignment between the humerus, radius, and ulna. The bones are no longer in their normal functional positions, indicating a complete dislocation of the elbow joint. Image by James Heilman, MD, CC BY-SA 3.0

Another way movement can be impaired is through joint-related injuries like **dislocations** and **subluxations**. These conditions occur as a result of physical trauma or impact, such as falls or movement beyond normal limits. Dislocation occurs when the bones of a joint are completely out of their functional position, leading to visible deformity, pain, swelling, and inability to use the joint. While subluxations are partial dislocations, bones are misaligned but maintain some contact with the typical and functional positioning of the joint.

11.6 INFLAMMATION

Inflammation is the body's natural way of protecting and healing itself when injury or infection is present. While helpful in some situations by responding to damage and sending immune cells to help address a given problem, inflammation can also result in difficulties moving.



“The four cardinal signs of inflammation”
by Koen Liddard, CC BY-NC-SA 4.0

If you have ever injured yourself, you may have noticed the injured area becoming red, swollen or enlarged, warm, and painful; these can all be signs of inflammation! As a result, the area or joint may have been hard to move through its full range of motion or at least was uncomfortable in doing so.

Generally, inflammation is a good sign and lets you know that the body is responding to an infection or injury. It does so by sending molecules to the area of concern to help do one of four things.

1. Defend against foreign and potentially harmful agents such as bacteria or viruses.
2. Prevents further injury by discouraging use of the area through pain, swelling, or both.
3. Promotes healing and repair by delivering Immune cells through increased blood flow
4. Removes unwanted or damaged cells from the area to make room for healthy cells and new growth.

However, some conditions are characterized by inflammation either globally throughout the body or locally within a specific body part or area. Although these conditions have various names, one commonality they have is their use of the suffix “-itis”. Knowing that “-itis” refers to inflammation, it becomes easy to identify conditions which describe inflammation in different parts of the body. Consider the following examples:

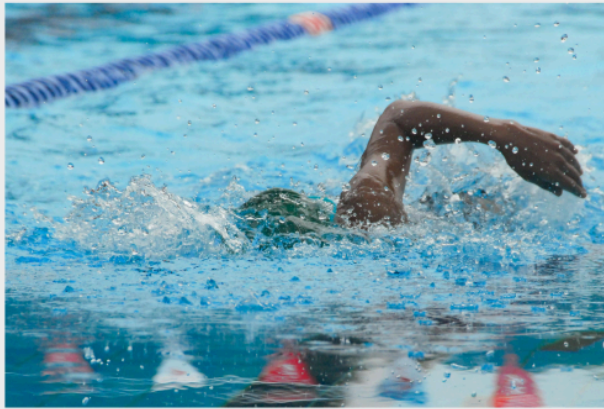
Bursitis

A condition describing inflammation of one or multiple **bursae**, a fluid-filled sac found throughout the body, which acts as a cushion between bones and soft tissues.

- Athletes who rely on overhead shoulder movement may experience subacromial bursitis, bursitis

of the bursa that sits approximately above the shoulder joint and below the clavicle or collarbone (left image below).

- Athletes who flex and extend their elbows frequently during physical activity may experience Olecranon bursitis.



Side-by-side photos of two athletes: on the left, a swimmer performing a freestyle stroke in a pool; on the right, a tennis player preparing to serve on a clay court, gripping a racquet and holding a tennis ball. “Swimming” (left) by Emily Rose, Pexels License, “Tennis” (right) by Gonzalo Facello, Pexels License

Tendinitis

A condition describing inflammation or irritation of a tendon, often caused by repetitive movements or overuse. A common type of **tendinitis** is “Tennis Elbow” where the tendons on the outside of the elbow are affected, or “Golfers Elbow,” where the tendon on the inside of the elbow is affected

Plantar Fasciitis

A condition describing inflammation of the plantar fascia, a thick band of connective tissue that runs along the bottom of the foot. A common cause of **plantar fasciitis** is high-impact activities such as running.

Arthritis

A general term for inflammation of the joint resulting in pain, reduced mobility, and swelling. While there are several types of **arthritis**, two commonly known types are osteoarthritis and rheumatoid arthritis.

Osteoarthritis

A condition associated with advanced age or overuse that has known ties to long-term inflammation. **Osteoarthritis** is caused by the wearing away of the joint cartilage that is supposed to cushion the joints, but is no longer able to.

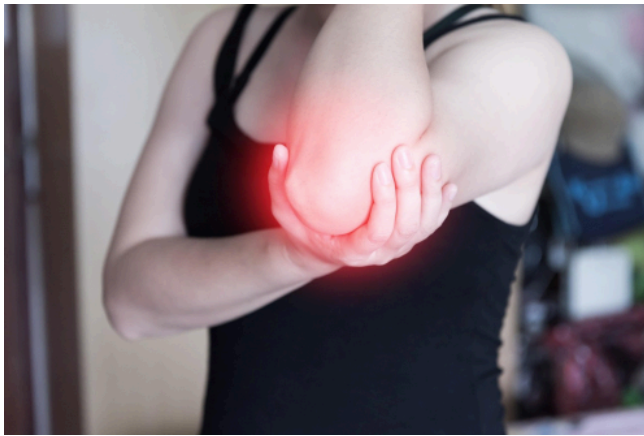
Rheumatoid Arthritis

An autoimmune disorder that impacts one or more joints. With **rheumatoid arthritis**, the body sees its own joint lining as a threat, causing an inflammatory response.

11.7 MUSCULAR DYSFUNCTION

Muscular dysfunction occurs when our muscles do not work properly, making movement harder to achieve. Such dysfunction could present itself as a lack of muscular strength, range of motion (ROM), coordination or control, and can arise from disorders of the muscles themselves, the nerves that control them, or larger conditions that impact the entire body.

The ways in which muscular dysfunction can affect the body include:



- Muscle weakness
- Limited range of motion
- Impaired coordination and motor control
- Muscular fatigue and decreased endurance
- Abnormal or "atypical" muscle tone
- Involuntary movements
- Loss of functional independence
- Pain and discomfort
- Postural deformities
- Impact on vital organs (lungs or heart)

Photo by nattan23, Pixabay License

Image Description

Image illustrating symptoms of neuromuscular or musculoskeletal disorders. On the left, a person holds their elbow in pain, with a red glow emphasizing discomfort. On the right, a list outlines common symptoms including muscle weakness, limited range of motion, impaired coordination, muscular fatigue and decreased endurance, abnormal or “atypical” muscle tone, involuntary movements, reduced independence, pain and discomfort, postural deformities, and impact on vital organs such as the lungs or heart.

Lack of muscular strength

Muscular Dystrophy (MD) is a type of genetic disorder characterized by progressive muscle weakness and muscle wasting due to the absence of specific proteins in the muscle. Although there are several types of muscular dystrophy which vary in symptoms and time of onset, the most common type is Duchenne Muscular Dystrophy (DMD), which primarily affects males during childhood. Over time, this condition leads to symptoms such as difficulty walking, frequent falls, and muscle wasting of skeletal and cardiac muscles.

Range of Motion Restrictions

Rigidity describes when skeletal muscle has increased muscle tone that is continuously resistant (stiff) to passive movement. Rigidity affects both agonist (or working) and antagonist (opposing) muscles equally and is not dependent on the rate at which movement is occurring. Commonly associated with **Parkinson's Disease**, for example, rigidity can lead to reduced flexibility and development of contractures, the permanent shortening of muscles and tendons.

Concerns with Coordination and Control

Similar to rigidity, **spasticity** is also characterized by increased muscle tone but does not impair movement in the same way. Spasticity differs from rigidity in that resistance (or stiffness) increases with faster movement and can exaggerate reflexes. Spasticity is common in a variety of conditions, such as Cerebral Palsy (CP), Multiple Sclerosis (MS), and Spinal Cord Injuries (SCI), and in those who have had a stroke. While symptoms may contribute to range of motion limitations, spasticity mainly impacts an individual's ability to produce coordinated and controlled movements due to involuntary contractions.

Watch the video “Understanding Spasticity” on WebMD to learn more about spasticity.

11.8 COMMON INJURIES

It is clear that human movement is dependent upon the complex interaction between many bodily systems that work together to function as a whole. However, the systems that allow this are vulnerable to a variety of injuries and conditions that can impair our movement. Within this section, several acute and chronic injuries will be discussed, as well as conditions that impact our ability to move.

Soft Tissue and Overuse Injuries

Sporting or physical activity-based injuries typically involve muscles, ligaments, tendons, joints and/or bones, and result from overtraining or overuse, poor technique/ improper form, lack of preparation, or direct trauma from an internal or external force. Such injuries can range from mild and not having to take a break from sport or physical activity to severe and impacting long-term function and performance.



Photo by Kindel Media, Pexels License

Soft tissue injury can include sprains (ligament damage) or strains (tendon and/or muscle damage), which were previously covered in Chapter 11.5, or **contusions** (or bruising) caused by direct blows to tissues resulting in bleeding beneath the skin. Soft tissue injuries can range from acute and mild to chronic, causing long-term performance and function deficits. For example, athletes will likely return to play after a contusion or even a mild, grade 1 sprain after sitting out a practice or two. However, after a grade 3 sprain of the ankle or a torn meniscus in the knee, an athlete will

likely have to sit out for the remaining season and return only after they've had extensive rehabilitation and/or surgery to repair the damaged tissue.

Overuse injuries can come in all shapes and sizes, from **stress (or hairline) fractures** of the tibia to dislocations of fingers. While competitive athletes are most susceptible to overuse injuries because they focus heavily on their sport of choice, everyone engaging in physical activity, athlete or not, is at risk for overuse injuries if activity or training exceeds the body's limits.

Signs of potential overuse injuries may include the following with regard to a specific area:

- Persistent pain: Dull or aching pain that does not go away with rest
- Swelling or inflammation: Area is warm and/or tender to the touch and/or stiff

- Reduced range of motion: Difficulty or inability to extend, flex or rotate a joint fully
- Weakness or fatigue: Muscles in the area tire faster than usual
- Decreased performance: Reduced speed, strength, or control when performing familiar movements
- Untimely pain or stiffness: Stiff after a period of inactivity or rest, and/or pain early in physical activity

Examples of Overuse Injuries

Click on each of the icons to learn more about the types of overuse injuries.

Text Description

A collage of four athletes representing different sports is used to explore examples of overuse injuries:

- Shin splints (a hurdler mid-jump): Pain along the tibia due to repetitive stress on the lower leg (e.g., running or jumping).
- Plantar fasciitis (a runner on a paved path): Heel pain caused by inflammation and irritation of the plantar fascia beneath the foot (e.g., common in runners).
- Rotator cuff Injuries (a baseball pitcher in mid-throw): Shoulder pain due to frequent overhead activity (e.g., swimming, baseball, or tennis).
- Spinal stress fractures (a gymnast performing a handspring): Pain of the spine/vertebra due to activity that involves repetitive impact or compression of the spinal column (e.g., gymnastics and football).

11.9 CONDITIONS IMPACTING MOVEMENT

In addition to injuries, several conditions can impact the way we move and function. This section will discuss how neurological, musculoskeletal, metabolic, and psychological conditions can impact our physical activity and movement.

Neurological Conditions

As already discussed in Chapter 10, our nervous system plays a crucial role in our ability to move by exciting muscle fibres to contract and providing **proprioceptive** information back to the brain. However, some conditions do not allow for appropriate communication between the brain, the control center of our nervous system, and our muscles. This can result in impaired movement. Some examples of neurological conditions include **Parkinson's Disease**, which causes bradykinesia (the slowness of movement), rigidity, and postural instability; Huntington's Disease, which causes involuntary movements and impaired muscle control; and **Vertigo**, which causes loss of balance or unsteadiness.

Musculoskeletal Conditions

In addition to the conditions discussed under the “Muscular Dysfunction” section, there are other musculoskeletal conditions that can impair movement in various ways. For example, joint replacements or repairs and limb amputations both can alter an individual's joint movement pattern or balance; restrict their movement for an extended period during rehabilitation; and require adaptation to an assistive device such as a brace or prosthetic limb. However, not all musculoskeletal conditions can be seen with the naked eye. **Osteoporosis** is a silent, but problematic diagnosis that describes bones being porous and fragile due to a lack of weight-bearing activity in the past. It is a condition characterized by low bone density and, therefore, increased bone fragility, which ultimately puts individuals at risk for fractures.



A man with a lower-limb amputation uses a resistance machine during physical rehabilitation. He wears a prosthetic leg, highlighting the use of assistive devices in recovery from musculoskeletal conditions. Photo by Kampus Production, Pexels License

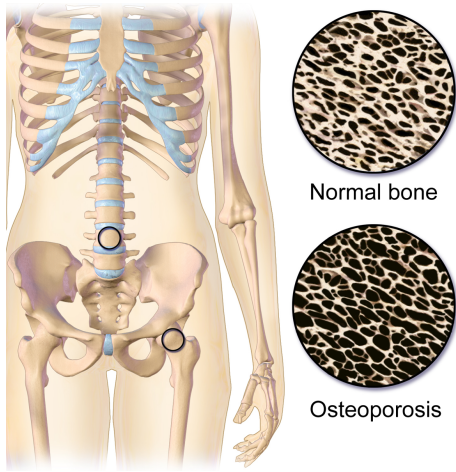


Illustration of a human skeleton highlighting common fracture sites affected by osteoporosis, such as the spine and hip. The two bone samples show a normal bone (dense structure), and osteoporotic bone (large pores/reduced density).
 “Osteoporosis Locations” by BruceBlaus, CC-BY-SA 4.0

Osteoporosis: A Disease of Youth?

Osteoporosis has traditionally been associated with older adults, as the risk of fragility fractures was considered significantly more threatening in this population compared to young individuals. However, research has identified that participation in weight-bearing activities, such as walking, running, weightlifting, etc., is incredibly powerful in building and maintaining bone density so that osteoporosis isn’t developed later in life. Therefore, while osteoporosis is a diagnosis many receive as an older adult, it’s one you can only help prevent as a younger person through physical activity and proper nutrition.

Metabolic Conditions

Metabolic conditions can also impact movement due to their energy-limited capacities and side effects. Some examples include:

- **Obesity:** Affects posture, endurance, movement efficiency, and joint loading
- **Diabetes:** Can cause proprioceptive deficits
- **Addison’s Disease:** Affects an individual’s physical stress tolerance and increases fatigue
- **Hypothyroidism:** Can cause muscle stiffness and fatigue, reducing the capacity to participate in physical activity

Psychological Conditions

Lastly, psychological conditions can also have a huge impact on human movement. While psychological conditions may not be visible, they can be just as inhibiting as a broken limb. For example, depression can reduce motivation to participate in physical activity and can increased levels of fatigue; eating disorders influence the type of nutrition being consumed and therefore influences what fuel muscles have to work with; and **fear of falling (FOF)**, a condition common in older adults with and without mobility concerns, can impact individual gait (i.e., walking pattern).

Key Aspects of Gait

Gait refers to the pattern of movement during walking or running, which is characterized by the key aspects below. Next time you are out walking or running, think about each component and how it changes from one activity to the next.

- Step length: How far each step takes you
- Stride: The cycle of steps you take between each strike of the same foot
- Cadence: The number of steps taken per minute
- Speed: How quickly a person walks
- Balance and Coordination: Ability to maintain upright, steady movement
- Symmetry: How evenly both sides of the body contribute to walking



Photo by wal_172619_II, Pixabay License

11.10 CHAPTER SUMMARY

Key Takeaways

- **Muscle Tissue Types and Function:** There are three types of muscle tissue: skeletal (voluntary movement), cardiac (involuntary rhythmic contractions of the heart), and smooth (involuntary movement in organs). All share properties like contractility, extensibility, and elasticity, which are essential for human function and movement.
- **Joints and Movement:** Joints are classified as synovial (freely movable), cartilaginous (slightly movable), and fibrous (immovable). Synovial joints, including hinge and ball-and-socket joints, play the most significant role in movement. Joint components like tendons, ligaments, menisci, and bursae provide support and reduce friction.
- **Soft Tissue and Joint Injuries:** Common injuries include sprains (ligament damage), strains (muscle or tendon damage), dislocations, and subluxations. These can result from overuse, trauma, or improper technique. Inflammation (e.g., tendinitis, bursitis) is the body's healing response, but it can impair motion when excessive or chronic.
- **Muscular Dysfunction and Disorders:** Movement can be impaired by muscular issues such as muscle weakness, rigidity, and spasticity, often due to conditions like muscular dystrophy, Parkinson's disease, or cerebral palsy. These dysfunctions reduce strength, coordination, and range of motion, sometimes affecting vital organs or posture.
- **Conditions Affecting Movement:** Neurological, musculoskeletal, metabolic, and psychological conditions can all impact physical function. Examples include

osteoporosis, obesity, diabetes, depression, and fear of falling. These affect energy, posture, motivation, proprioception, and gait, demonstrating how holistic body health is essential to movement.

OpenAI. (June 17th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Summarize the following content into five key takeaways.

Key Terms

- **Addison's Disease:** A disorder affecting hormone production, causing fatigue and reduced stress tolerance.
- **Arthritis:** Inflammation of joints, resulting in pain, stiffness, and reduced movement.
- **Bursa (Bursae):** A fluid-filled sac that reduces friction between bones and soft tissues, but when inflamed, is known as bursitis, which causes pain and can restrict movement.
- **Contusion:** Bruising caused by a direct blow, resulting in internal bleeding under the skin.
- **Depression:** A mental health condition that can reduce motivation, energy, and participation in physical activity.
- **Diabetes:** A metabolic condition that can impair nerve function and reduce proprioception.
- **Dislocation/ Subluxation:** Complete/ Partial separation of bones in a joint from normal position.
- **Elasticity, Extensibility, and Contractility:** The ability of a muscle to return to,

stretch beyond, and shorten compared to its resting length.

- **Fear of Falling (FOF):** A psychological condition that affects walking and balance due to anxiety about falling.
- **Hypothyroidism:** A condition that slows metabolism and can cause muscle stiffness and fatigue.
- **Inflammation:** The body's protective response to injury or infection, causing swelling, pain, and heat.
- **Ligaments:** The connective tissue which connects bone to bone, which works to stabilize joints and limit movement (e.g., your medial cruciate ligament or MCL in your knee, restricts side-to-side movement outside of typical hinge joint flexion and extension).
- **Menisci:** Crescent-shaped cartilage that absorbs shock and helps distribute joint pressure.
- **Muscular Dystrophy (MD):** A group of genetic disorders causing progressive muscle weakness and wasting.
- **Osteoarthritis:** A degenerative joint condition caused by wear and tear of cartilage.
- **Osteoporosis:** A condition where bones become weak and brittle due to low bone density.
- **Parkinson's Disease:** A neurological condition causing tremors, rigidity, and slowed movement.
- **Plantar Fasciitis:** Inflammation of the plantar fascia, a thick band of tissue along the sole of the foot.
- **Proprioceptive:** The body's ability to sense movement, action, and location.
- **Rheumatoid Arthritis:** An autoimmune condition causing chronic joint inflammation.
- **Rigidity:** Increased muscle tone that resists movement equally in both directions and speeds.
- **Sliding Filament Theory:** Explains muscle contraction via action and myosin filaments sliding past each other within the sarcomere (the smallest functional unit of muscle contraction).
- **Spasticity:** Increased muscle tone with resistance that increases with movement

speed; often causes jerky movements.

- **Sprain:** Injury to a ligament due to overstretching or tearing.
- **Stress Fracture:** A small crack in bone caused by repetitive force or overuse.
- **Strain:** Injury to a muscle or tendon due to overstretching or overuse.
- **Synovial Joint:** A freely movable joint with a fluid-filled cavity, such as the knee or shoulder.
- **Tendons:** The connective tissues which connect bones to muscles and transmit force from muscle to produce movement (e.g., the patellar tendon connects the quadriceps muscle group to the tibia and plays a key role in knee extension).
- **Tendinitis:** Inflammation of a tendon, often from repetitive motion.
- **Vertigo:** A condition causing dizziness or a sensation of spinning, affecting balance.

OpenAI. (June 10th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: List the key terms and their definitions in the content provided.

11.11 KNOWLEDGE CHECK

Knowledge Check

Text Description

1. Which of the following is a characteristic unique to cardiac muscle tissue?
 - Voluntary control and striated appearance
 - Involuntary control and no striations
 - Involuntary control and rhythmic contractions
 - Voluntary control and smooth texture
2. What structure in skeletal muscle is responsible for contraction and shortening of the muscle?
 - Myofibril
 - Sarcomere
 - Sarcolemma
 - Z Line
3. Which type of joint allows for the greatest range of movement?
 - Fibrous Joint
 - Cartilaginous Joint
 - Synovial Joint
 - Suture Joint
4. A sprain involves damage to which of the following structures?

- Muscle
- Tendon
- Ligament
- Bone

5. Which condition is characterized by involuntary muscle contractions that worsen with faster movement?

- Rigidity
- Spasticity
- Muscular Dystrophy
- Arthritis

6. Which of the following is false about osteoporosis?

- Weight-bearing activities can help maintain bone density
- Osteoporosis is reversible
- Osteoporosis has been referred to as a “Disease of Youth.”
- Risk of fractures is increased in those with Osteoporosis.

7. Which condition is associated with degeneration of joint cartilage due to aging or overuse?

- Rheumatoid Arthritis
- Osteoarthritis
- Bursitis
- Tendinitis

Correct Answers:

1. Involuntary control and rhythmic contractions
2. Sarcomere
3. Synovial Joint

4. Ligament
5. Spasticity
6. Osteoporosis is reversible
7. Osteoarthritis

OpenAI. (June 17th, 2025). ChatGPT. [Large language model]. <https://chat.openai.com/chat>. Prompt: Please create seven multiple-choice questions with answers based on the content shared.

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VERSION HISTORY

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.1. If the edits involve a number of changes, the version number increases to the next full number.

The files posted alongside this book always reflect the most recent version.

Version	Date	Change	Affected Web Page
1.0	August 24, 2025	First publication	N/A

INSTRUCTOR SLIDE DECKS



Slide Decks

- Chapter1_Study_of_Human_Movement
- Chapter2_FITT_Principle
- Chapter3_Anatomical_Terminology
- Chapter4_Skeletal_System
- Chapter5_Muscular_System
- Chapter6_EnergySystems
- Chapter7_Biomechanics
- Chapter8_Upper_Body_Exercises
- Chapter9_Lower_Body_Exercises
- Chapter10_Exercise_Neuroscience
- Chapter11_Tissues_Joints_Pathologies