12

Biomechanics

PART 1

Sir Isaac Newton (1642–1727), English physicist, mathematician, and alchemist.

OBJECTIVES

- Explain the differences between statics and dynamics.
- Compare and contrast osteokinematics and arthrokinematics.
- Define force and torque; give an example of how they are seen in movement.
- List the physical laws and principles involved in biomechanics, such as friction, vector, velocity, and momentum.
- Identify and describe gravity's role in movement.
- Summarize Newton's three laws of motion and how they relate to human movement.

THE ESSENCE OF THIS CHAPTER

At the end of a high school physics class, Tara crumpled her quiz paper into a ball and dropped it on Mr. Marko's desk. "Physics," she declared, "has nothing to do with my life."

Mr. M smiled, "Tara, you play soccer, right? Let's imagine your wadded-up quiz is the ball."

He swatted it with his finger and it rolled across the desk into her hands.

"Hmm, that's strange. We just demonstrated Newton's First Law of Motion."

"We did?"

"What was the ball doing before I hit it?"

She thought, "Uhh, not moving?"

"Yes. But why?"

"Oh, I know this—*an object at rest tends to stay at rest*."

He got up from his chair. "So true. Then what happened?"

"You hit it, it rolled, and I stopped it."

"Aha! *An object*—"

"—*in motion tends to stay in motion*!" she exclaimed.

"You know, there's a reason they're not called Newton's *Suggestions*. If they were, soccer—and the rest of the universe—would be chaos."

She uncrumpled the paper. "Like my quiz."

"Luckily, Marko's Law states that learning is a journey. Hand it in tomorrow." Keep Marko's Law in mind as we delve into a branch of physics that has much to do with your life: biomechanics.

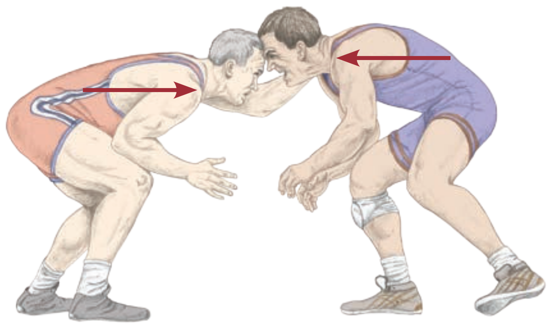
- **If Tara pushed a soccer ball and a bowling ball on a paved surface with the same amount of force, which one would travel farther? Why would it travel farther?**
- **What are some examples of ways we, as bodyworkers, can use the force of gravity to our advantage?**
- **You are about to pick up a box that you believe is filled with textbooks but is, in fact, empty. What will happen when you pick it up? How would this result differ if the box was full of books but you believed it was empty?**

IN THIS CHAPTER

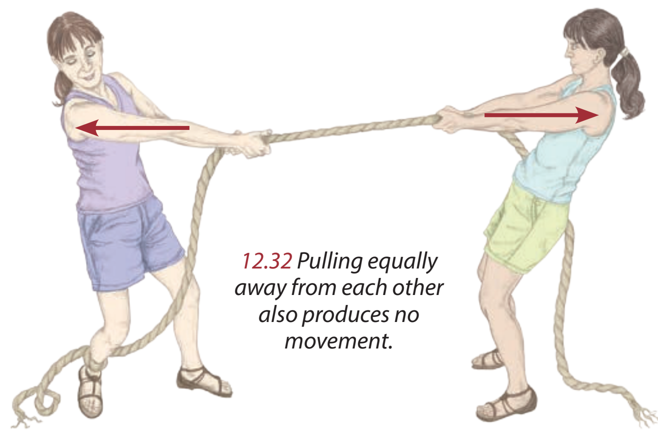
Force in Depth

We briefly described force on page 175. Now let's delve deeper. As we mentioned, force is *any influence that causes an object to undergo a certain change*. To generate a force, one object (say, a fist) must act on another (a punching bag). And as we saw in the conversation about connective tissue (page 31), force can present itself as a *push* or a *pull*. (Twist, shear, and other distortions are just variations on those themes.)

When two objects push toward or pull against each other *equally*, stillness results (12.31, 12.32). But when one force is greater than the other, we've got movement. It is also worth remembering here that force can be generated from either *inside* the body (muscles, fasciae, bones) or *outside* the body (gravity, friction, wind). In the examples forthcoming, we'll witness both types.



12.31 Pushing equally toward each other results in no movement.



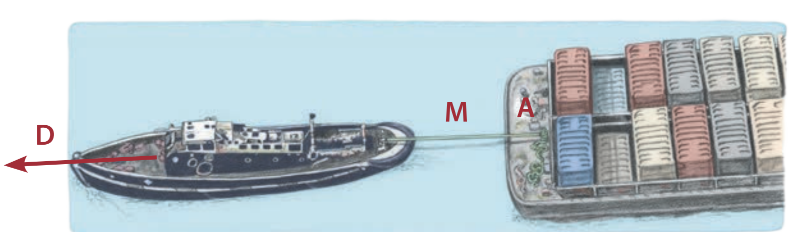
12.32 Pulling equally away from each other also produces no movement.

A Review of Force and Vectors

Before we delve into the three different force systems, let's first recognize that force (*any influence that causes an object to undergo a certain change*) is *a vector quantity*. And a vector (as we discussed on page 176) is simply *a force with direction and magnitude*. For example, you describe a vector quantity when offering direction to a friend: "Go west for two blocks." *West* is the direction and *two blocks* is the quantity (magnitude).

Force possesses both of these characteristics (**magnitude** and **direction**) as well as having a **point of application**. And a change in any of these three components will affect the movement involved.

For instance, imagine a tugboat pulling a barge. The amount of tension on the towrope illustrates the vector's **m**agnitude (M), and the tug's course represents the vector's **d**irection (D) (12.33). Its point of **a**pplication (A) is where the rope attaches to the barge's bow.

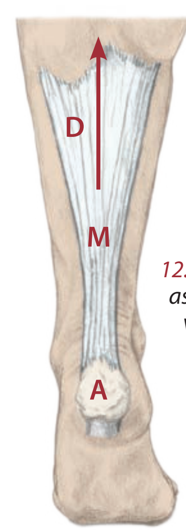


12.33 A tugboat applies direction, magnitude, and a point of application when pulling its load.

An anatomical example of force as a vector quantity can be seen when you stand up on your toes (12.34). The tension on the triceps surae tendon represents the vector's **m**agnitude (M), the muscle's line of pull (rising superiorly) illustrates the vector's **d**irection (D), and the point of **a**pplication (A) is on the posterior calcaneus.

As we'll see next, we can use these three aspects of force to create three different kinds of force systems:

- **linear**
- **parallel**
- **concurrent**



12.34 Plantar flexion as an example of a vector quantity.

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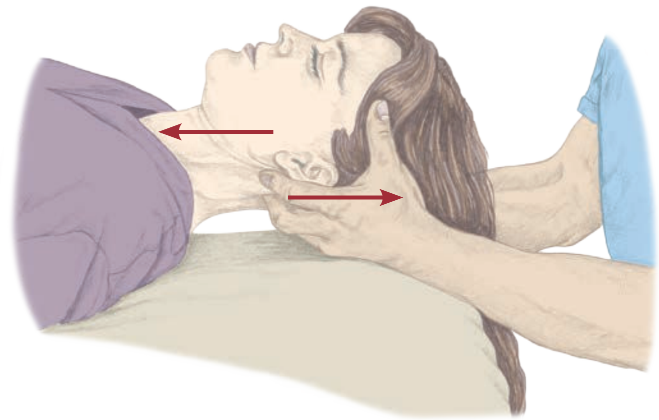
Linear Force

Your client is lying supine and you apply cervical traction to her neck (12.35). This is an example of **linear force**—*when all forces occur along the same line of pull*. Here, traction is produced by having your hands move *toward* you while her head and neck (via the internal tension of the tissues) resist your effort along the same line of pull.

Linear forces may act in the same direction or opposite directions and may produce tension or compression. In the case above, your hands generate *tension* (or a pulling force on the head), and linear forces move in opposite directions.

Alternatively, linear forces generating compression can be seen when your client is supine and you flex his hips and knees (12.36). By standing inferior to your client's body, you can compress (push) the tissue whereby linear forces move toward each other.

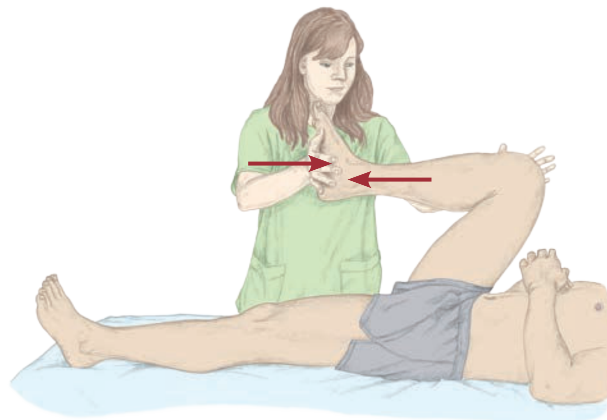


12.35 Cervical traction where linear forces move in opposite directions.

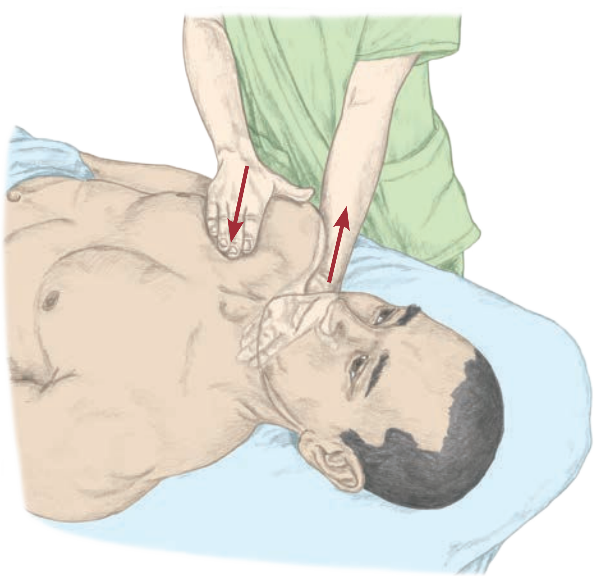
Parallel Force

Now let's move to the shoulder. Standing at your client's side, you set one hand on top of his shoulder while the other hand scoops underneath it. As you apply pressure in opposite directions (your top hand slides medially while your bottom hand pulls laterally), you produce parallel forces (12.37).

Parallel forces *are aligned with each other, but are either adjacent to each other (laterally displaced) or acting at different depths* (like your hands in the above scenario). They can move in the same direction or opposite directions. An anatomical example of parallel force (and one where the forces move in the same direction) is seen in the engagement of the hamstrings (12.38). The muscle bellies are situated within the same plane, function in a side-by-side fashion, and move the knee in the same angle.



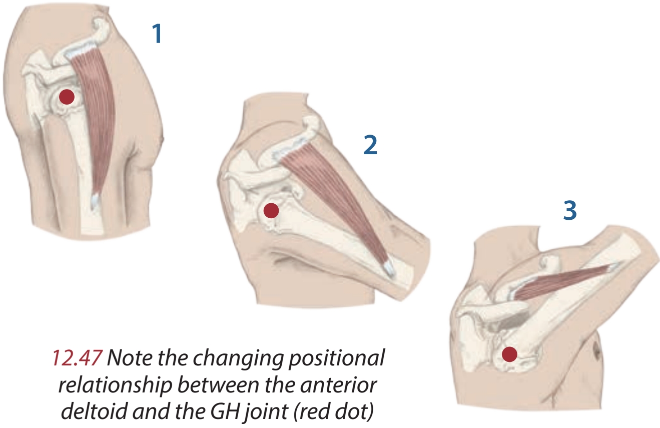
12.36 Linear forces acting in the same direction during flexion of the hip.



12.37 Parallel forces: applying pressure on opposite sides of the shoulder.

12.38 Parallel lines along the hamstrings.

BIOMECHANICS

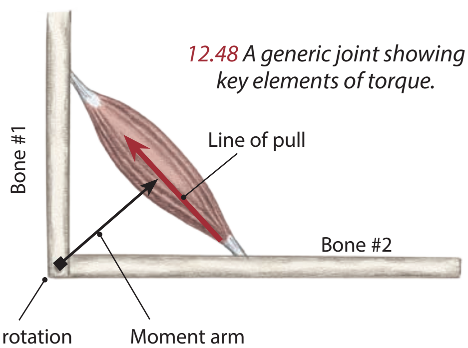


12.47 Note the changing positional relationship between the anterior deltoid and the GH joint (red dot) during flexion of the shoulder.

As we stated on the previous page, torque is "a force that involves *rotation of an object about (around) an axis*." Now let's look at this concept in relation to joints and muscles. Here's the setup: Movement at most of your articulations involves some type of rotary motion (rotation). Flex your knees, extend your fingers, rotate your neck—all of these involve rotation around joints. For those actions to occur, a muscle is required. More specifically, a muscle contraction that will generate a quantity of force to create torque (rotation) at the joint.

With this in mind, here's something you might not have considered: The *positional relationship* between a muscle and the joint it moves is constantly changing during a movement.

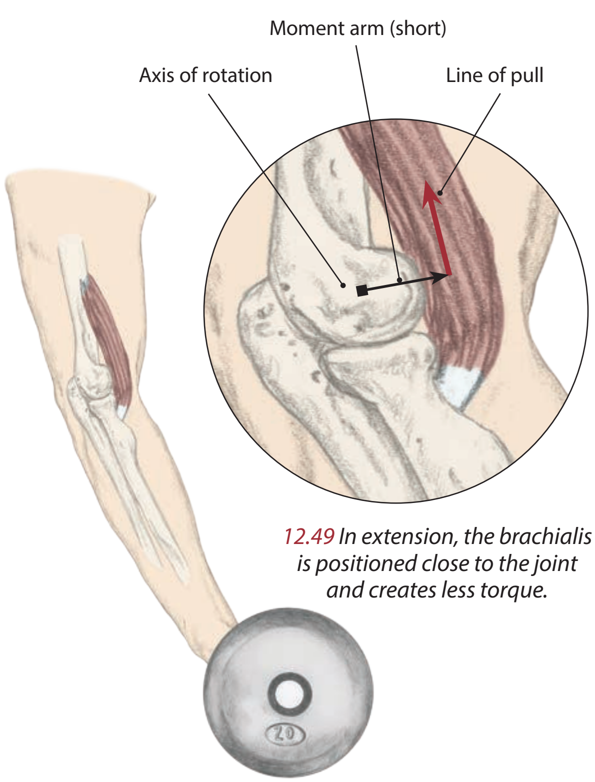
For example, as your shoulder passes through 180° of shoulder flexion, the position of your anterior deltoid (as well as its attaching tendons) will continually change with respect to your glenohumeral joint (12.47). Because of the variable nature of this association, *the amount of torque generated through the range of motion will change as well*.



12.48 A generic joint showing key elements of torque.

We can explore this further by examining a "generic joint" and its components as they relate to torque. Our simplified joint (12.48) includes a **line of pull** (which passes through the muscle belly, page 130) and an **axis of rotation** (located at the center of the joint). Spanning between these points is a **moment arm** (or torque arm), *the perpendicular distance between the muscle's line of pull and the axis of rotation*.

As we said above, the amount of torque produced at a joint depends upon (1) the strength of a muscle's force (magnitude) and (2) the *perpendicular distance* between the line of pull and the axis of rotation. This distance (the length of the moment arm) will change over the course of a joint's range of motion and, correspondingly, so will the amount of torque. As we'll see in a moment, when a joint's line of pull is at 90°, torque is at its greatest. But when the angle of that joint increases or decreases from that perpendicular angle, torque decreases.



12.49 In extension, the brachialis is positioned close to the joint and creates less torque.

Let's apply these concepts to the brachialis. When the elbow is extended, the muscle belly of the brachialis is closely situated to the humeroulnar joint (12.49). This position creates a short moment arm. Without getting into all of the mathematics, this means that when the elbow is in an *extended* position, the brachialis produces less torque.

Similarly, in a fully *flexed* position, it possesses diminished rotary force (12.51). However, when the joint is positioned at 90°—and the moment arm is at its *longest* (12.50)—it can generate the most torque. (This coincides with our discussion on page 137 about how a muscle, via its sarcomeres, is strongest in its midrange position.)

Now, you might be puzzled as to why the length of the moment arm (the span between the line of pull and axis of rotation) has such a large impact on a muscle's capabilities. After all, it's only a small change in distance from one position to the next. But, in fact, that small alteration determines not only a muscle's biomechanical potential but also *the type of force* it will generate on a joint.

Review Questions for Biomechanics, Part 1

(Find the answers online at booksofdiscovery.com "For Students")

1. **Biomechanics is defined as the:**
   (p. 174)
   - **a.** Physical laws of biology that relate to mammals
   - **b.** Mechanical principles that directly relate to the body
   - **c.** Mechanical aspects of biology and science
   - **d.** Biological principles that involve human movement

2. **A force can occur in what ways?**
   (p. 175)
   - **a.** Direction, movement, and structure
   - **b.** Direction, stability, and strength
   - **c.** Stability, mobility, and function
   - **d.** Movement, structure, and function

3. **A rolling ball that meets no resistance and continues to travel is an example of:**
   (p. 175)
   - **a.** Mass
   - **b.** Torque
   - **c.** Inertia
   - **d.** Gravity

4. **A force that resists the relative motion of two surfaces is:**
   (p. 176)
   - **a.** Vector
   - **b.** Friction
   - **c.** Statics
   - **d.** Dynamics

5. **Which of the following has the greatest effect on your physical movement?**
   (p. 177)
   - **a.** Flexibility
   - **b.** Gravity
   - **c.** Strength
   - **d.** Time

6. **Running into a brick wall illustrates which of Newton's three laws of motion?**
   (p. 178)
   - **a.** Law of Inertia
   - **b.** Law of Action
   - **c.** Law of Acceleration
   - **d.** Law of Mobility

7. **Which of the following are critical factors of Newton's Second Law of Motion?**
   (p. 179)
   - **a.** Mass, vectors, and gravity
   - **b.** Force, gravity, and light
   - **c.** Vectors, gravity, and acceleration
   - **d.** Force, mass, and acceleration

8. **Stepping off of a free-floating canoe and onto an unstable dock is an example of:**
   (p. 181)
   - **a.** Vector and force
   - **b.** Action and reaction
   - **c.** Acceleration and deceleration
   - **d.** Force and stability

9. **Force can be divided into which three systems?**
   (p. 182)
   - **a.** Circular, collateral, and striated
   - **b.** Linear, perpendicular, and vector
   - **c.** Linear, parallel, and concurrent
   - **d.** Oblong, simultaneous, and regional

10. **Turning a wrench is an example of:**
    (p. 185)
    - **a.** Torque
    - **b.** Gravity
    - **c.** Vector
    - **d.** Force