CHAPTER 5

Muscles at Work

After completing this chapter you should be able to:

- differentiate between the various types of muscle contractions;
- describe the factors that influence strength development;
- identify the components of strength;
- discuss the relationships between the various components of strength.

Muscle is an organ that creates movement. Its structure and function presented in the previous chapter adapts according to some important training principles. These principles are designed to improve general and specific fitness, which is an important component of overall health. However, before we present the various principles of training in Chapter 15, you must become familiar with the various types of muscle contraction. You must also understand the concept of muscular strength, its components, and the interrelationships between these components, which provide the basis of training for fitness and athletic performance.

Types of Muscle Contraction

Several types of muscle contraction are relevant to a fitness and strength training program. The first distinction is made between static and dynamic contraction.

Static and dynamic work involves four types of muscle contraction: isometric, isotonic, isokinetic, and plyocentric. Each of these types of contractions is further divided into two forms of movement: concentric and eccentric.

Did You Know?

It is interesting to note that the terminology for major muscle contractions has been developed from the Greek language (Figure 5.1).

Static Contraction

Static contraction refers to a contraction in which the muscle tension or force exerted against an external load is equal or weaker, so no visible movement of the load occurs. Consider an athlete who attempts to flex an arm against the resistance of a fixed bar. Even if all energy and strength are mobilized, the athlete will not succeed in moving the arm or the bar. Nonetheless, the exerted muscle force is substantial.

In most sports, maximal static tension is rare. It may occur, however, in gymnastics (in the iron cross and hanging scale) or in wrestling and judo (in floor grips, holding techniques, and bridges). In general, most sport activities require low to **submaximal static contraction**. Sailing in close contact with the wind, shooting, and alpine downhill events often require static work over extended periods (Figure 5.2).

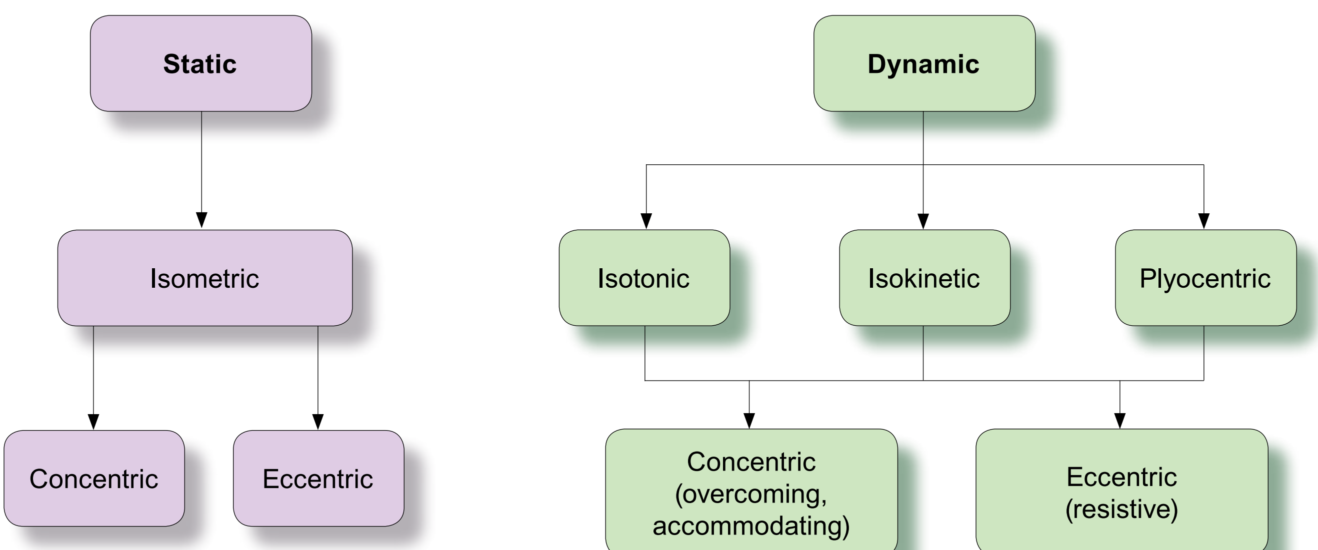


Figure 5.1 Types of muscle contractions.

A **B**

Figure 5.2 Static or isometric contractions. **A.** Activities requiring maximal static muscle tension. **B.** Activities requiring submaximal static muscle tension.

Isometric Contraction

An **isometric contraction** (*iso* = same, *metric* = length) is one in which there is no visible change in muscle length, even though the muscle has undergone muscle contraction. In this case, the contraction is against a load that is beyond the capability of the muscle(s) to move, and therefore, no movement of the load occurs. We also know that considerable force has been produced by the tiredness that one feels. The issue here is that no external movement is registered. Isometric contraction is a static contraction.

Strictly speaking, no work is performed during an isometric contraction (work = force x distance); nonetheless, a relatively high amount of tension is developed and energy is used. Therefore, an isometric contraction is not defined by the work performed but by the rate of tension developed and by the duration over which the tension lasts.

When two individuals of equal strength compete in arm wrestling, an isometric contraction occurs. There will be no movement of the hands until one individual fatigues (loses some of the cross bridges) and therefore can no longer maintain the status quo. For more on cross bridge formation, see Chapter 4.

Can you name other activities that are based on isometric contraction?

Dynamic Contraction

The neuromuscular system is said to work dynamically if internal and external forces are unbalanced. For instance, an athlete may be able to exert enough force to lift a weight through the full range of an exercise. When the external force (gravity of a weight or object) is smaller than the internal force generated by the athlete, the latter will be able to resist, and the result will be movement. Thus, a **dynamic contraction** involves movement.

Isotonic Contraction

Under normal circumstances, dynamic work is based on **isotonic contraction** (*iso* = same or constant, *tonos* = tension). Because of the continual change in joint angle and speed that occurs during dynamic work, the muscle needs to contract at either increasing or decreasing tension. The constant addition or subtraction of motor units recruited causes the muscle to adapt to constantly changing tension requirements. Isotonic contraction is a dynamic contraction.

When an athlete bends the arms while holding a barbell, the mass of the barbell obviously remains the same or constant during the entire range of movement. The strength needed to perform this movement is not, however, constant, but depends upon the physique of the athlete, the athlete's leverage, the angle position of the limbs, and the speed of movement (Figure 5.3). Also see Figure 4.5 in Chapter 4.

Lateral arm raises, too, require greater strength initially, reaching a maximum at 90 degrees and then dropping constantly. When lifting the trunk from a horizontal position, an athlete needs to mobilize maximal strength at the beginning of the movement, gradually reach peak values, and then decline continuously toward zero.

The issue of changing muscle force or tension throughout a movement also poses a problem to those using free weights to train. What often happens is one of two scenarios. If the chosen load can be lifted throughout the complete range of motion, it provides adequate stress for training in the initial and final stages of the movement but does not stress the muscle as much in the area of movement corresponding to optimal cross bridge formation. It is often in this area that the athlete wants to train, whether it is for the development of additional strength or the building of muscle bulk.

If the load is chosen to provide training stress to the muscle in that part of the range of movement corresponding to optimal cross bridge formation, then the load is often too great for the individual to be able to move at either end of the complete range of movement. In this case, the individual often gets the bar moving by "bumping" it with his thighs, and, at the end of the curl, lets it fall onto the shoulders. When lowering the bar, the

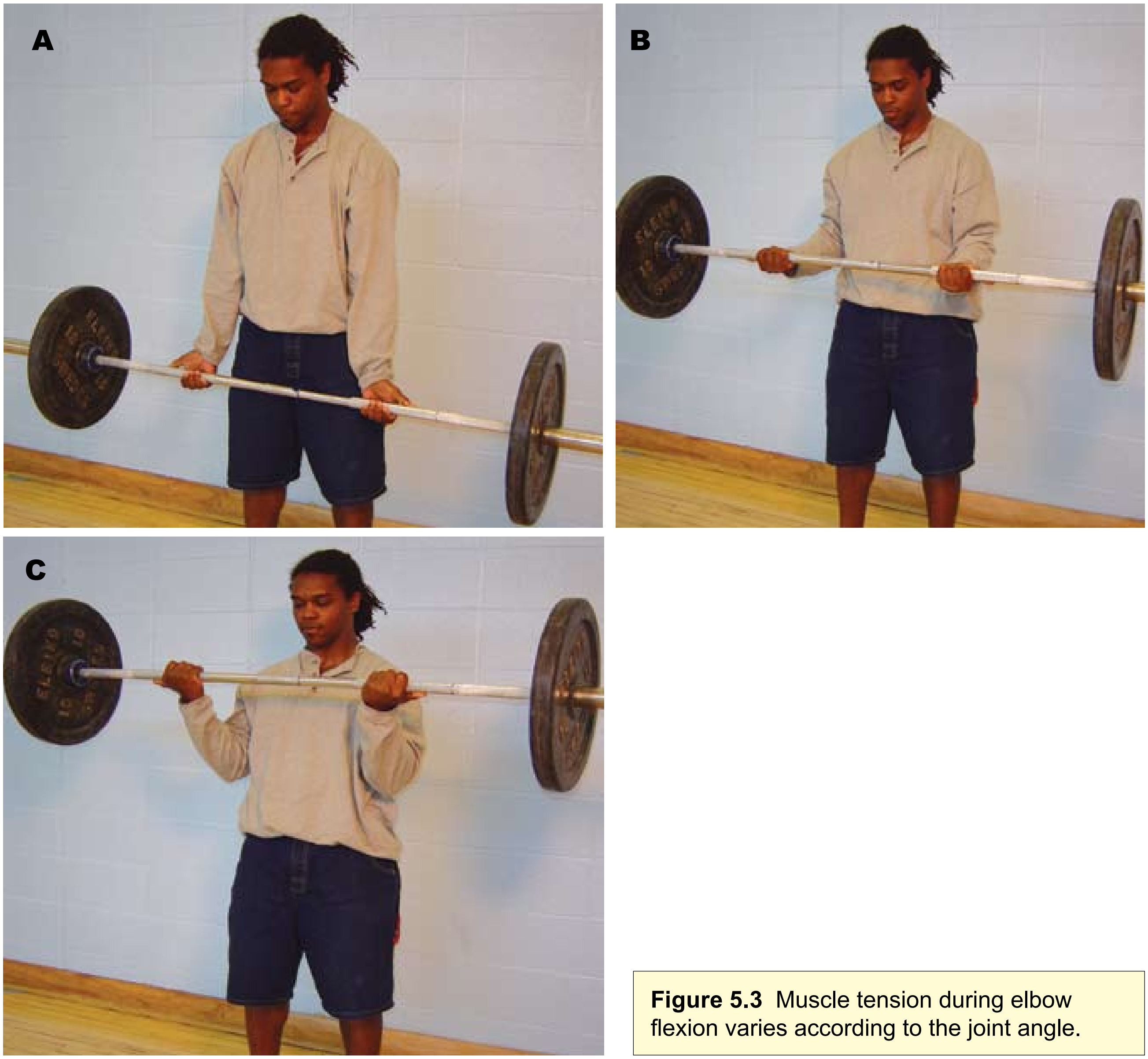


Figure 5.3 Muscle tension during elbow flexion varies according to the joint angle.

first movement is to drop the bar until sufficient cross bridges can form to stop its falling, and the movement ends with the bar falling onto the thighs.

Most often, the latter course of action is taken, and the result is that the individual does not train throughout the full range of motion, often resulting in the appearance that the arms can't be straightened! What you would like to do is optimally stress the muscle throughout the range of motion. To do this, the load must be increased as the lift is made and then decreased as you pass the region where optimal cross bridge formation occurs, a difficult task to say the least when training with free weights.

Isokinetic Contraction

In **isokinetic contraction** (*iso* = same or constant and *kinetic* = motion), the neuromuscular system can work at a constant speed during each phase of movement (despite the constantly changing leverage or torque) against a preset high resistance. This allows the working muscles and muscle groups to release high tension over each section of the movement range. This type of contraction is effective for strengthening the musculature uniformly at all angles of motion.

As in the auxotonic contraction, however, the precise amount of muscle tension release is always dependent upon the corresponding joint angle and the velocity of movement. This is accomplished, with varying degrees of success, by a number of expensive dynamometers, including the Cybex, the Kin-Com, and the Lido, which keep the speed of movement constant electronically, and the HydraGym and Nautilus, which use mechanical means to produce movements that are "isokinetic" in nature (Figure 5.4).

The relatively constant speeds involved in swimming and rowing are similar to those produced in isokinetic exercise forms. For this reason, these sports use isokinetic training to increase performance levels. However, the majority of sports contain few pure isokinetic movements as they continuously require changes in velocity and force application throughout movements.

Isokinetic contractions are classified as dynamic contractions.

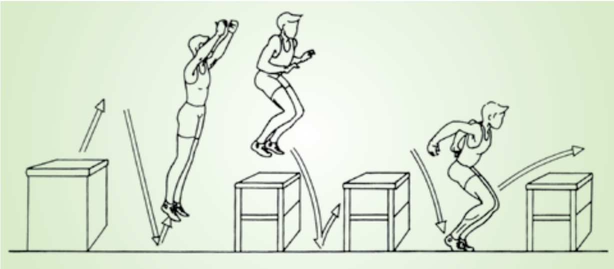
Plyocentric Contraction

The last type of muscle contraction, a **plyocentric contraction**, is a hybrid contraction in that the muscle performs an isotonic concentric contraction

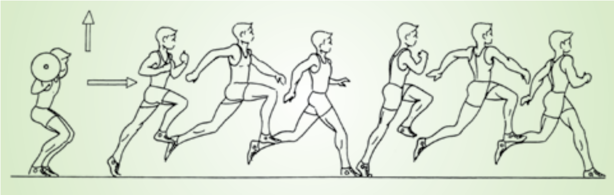
Figure 5.4 Isokinetic contractions are generated by a variety of very expensive dynamometers.

> **Which Is Best?**
>
> Isotonic muscle contractions involving dumbbells and barbells are considered to be the most effective method for developing overall strength.

from a stretched position. The "prestretching" of the muscle is achieved by jumping off an object (box) from a height of 10 to 15 inches, or 25 to 40 cm (depth jumping).



This not only prestretches the muscles but also sets off the **Golgi tendon organ** reflex, which functions to protect the muscle from too much stretch. The reflex causes the muscles to contract. Activities that utilize this type of contraction to train jumping ability include leaping and bounding, such as in plyometric training.



Research has shown that this type of strength and power training leads to a greater increase in jump height than that developed by strength training alone.

Concentric and Eccentric Contractions

A **concentric contraction** is one in which the muscle shortens as it goes through the range of motion; this is usually termed **flexion.** An **eccentric contraction** is one in which the muscle lengthens during the movement, usually termed **extension**. Again, let's use the arm curl with free weights as an example (Figure 5.3). The movement of the bar from the thighs to the shoulder region (i.e., flexion of the biceps brachii) is an auxotonic concentric contraction. The movement from the shoulder area back to the thighs (i.e., extension of biceps brachii) is an isotonic eccentric contraction.

Factors Influencing Muscle Contraction

There are numerous factors that can affect the force and power output of a muscle, including the individual's **state of health** and **training status**. Other factors that affect force and power output include: (1) joint angle; (2) muscle cross-sectional area; (3) speed of movement; (4) muscle fiber type; (5) age; and (6) sex.

Joint Angle

Let us again consider the example of elbow flexion during a barbell lift (Figure 5.3). Contraction of the elbow flexors is initially isometric (static). The muscle does not visibly shorten until after the internal forces generated by muscle flexing exceed the external forces of the barbell. As the arms flex at the elbow joints, the barbell is moved toward the shoulders. The barbell accelerates in proportion to the degree that the internal forces exceed the load of the barbell. A short phase of static work, often lasting only a few hundredths of a second, occurs between the dynamic work of concentric contraction and the lowering of the barbell.

On lowering the barbell into its initial position, external forces exceed internal ones. The same muscles that previously were involved in lifting the barbell are now being stretched, and with the arms extended at the elbow joint, the barbell is lowered. Elbow flexors, which on lifting the load performed dynamic concentric contractions, are now involved in lowering the load by performing dynamic eccentric contractions. The greater the

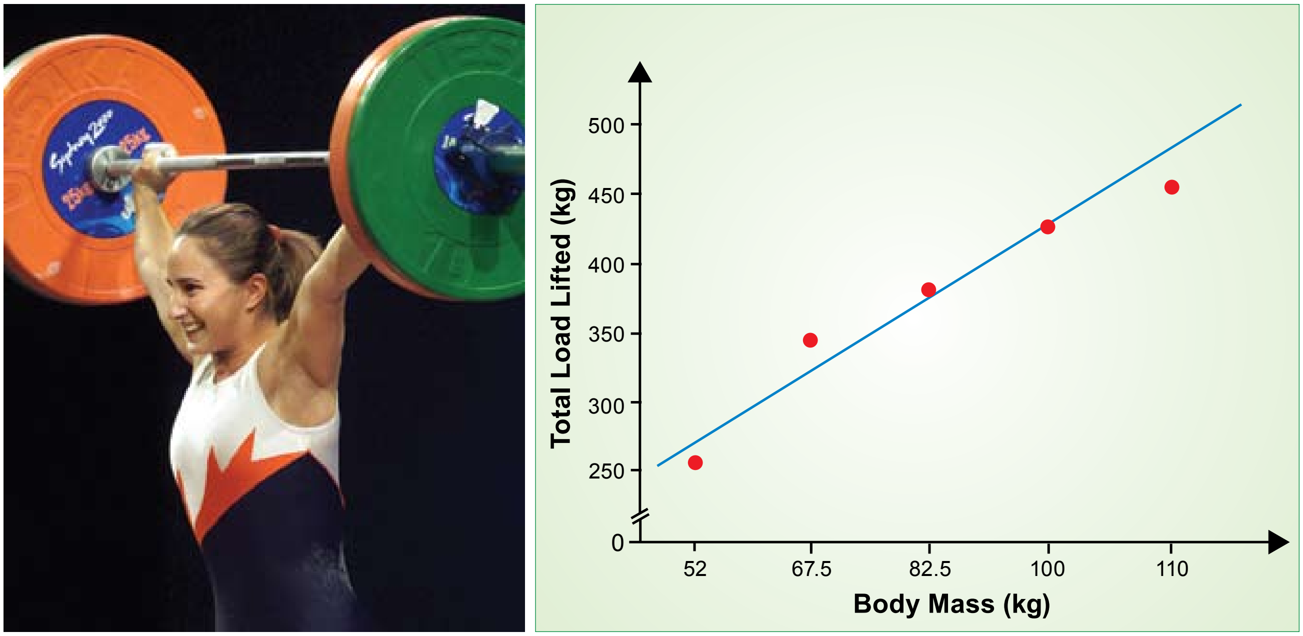


Figure 5.5 Relationship between body weight and maximal load lifted for the combined clean and jerk and snatch events (data from the Seoul Olympics weightlifting competition).

external force, the higher the speed at which the load is lowered. "Muscle teamwork" (agonist versus antagonist) was discussed in Chapter 4.

An athlete doing knee bends performs an eccentric contraction during the flexing phase and a concentric contraction during the ensuing extension phase.

Athletic activities involving only one muscle or muscle group are rare. During each phase of movement, some muscles contract in a dynamic concentric mode, others in a dynamic eccentric mode, and some contract statically. For example, an athlete doing knee bends activates over 75 percent of the body's skeletal musculature to generate the total movement.

Muscle Cross-sectional Area

Human beings have always recognized the close connection between body mass and strength. The relationship between body mass and strength is indeed valid. The greater one's stature, the greater one's strength – provided body mass is composed mainly of muscle and not fat. In other words, strength is determined by the volume of active body matter (i.e., the entire body mass minus body fat). This mass is also referred to as the fat-free or lean body mass (see discussion on this topic in Chapter 17). This fact has been emphasized by the performances of weightlifters across various weight categories (Figure 5.5). The world record in the 62-kg division is greater than that in the 52-kg division; and in the 85-kg division, it is higher than in the 62-kg division. The heaviest weights of all are lifted by athletes in the superheavyweight category (in excess of 105 kg).

Maximal or Absolute Strength

From the above discussion we can conclude that the greater the active body mass, the greater the maximal or **absolute strength**. This general rule is based on the notion that strength depends to a high degree on the size of the muscle cross-section (Figure 5.6). However, this statement requires qualification. Because intra- and intermuscle coordination, anatomical structure, and the elasticity of muscle also play an important part in the performance capacity of the muscle, it is