Resistance exercise has proven to be a safe and effective method of conditioning for individuals with various needs, goals, and abilities. Though much of what we understand about the stimulus of resistance exercise has been gained through examination of the acute and chronic responses of adult men to various training protocols, resistance exercise for children, women, and older people has received increasing public and medical attention in recent years. When designing and evaluating resistance training programs, strength and conditioning professionals need to understand age- and sex-related differences in body composition, muscular performance, and trainability and their implications for each individual.

For the purposes of this chapter, resistance exercise is defined as a specialized method of conditioning that involves the progressive use of resistance to increase one’s ability to exert or resist force. This term should be distinguished from the sport of weightlifting in which individuals attempt to lift maximal amounts of weight in competition. The term preadolescence refers to a period of life before the development of secondary sex characteristics (e.g., pubic hair and reproductive organs), and the term adolescence refers to the period between childhood and adulthood. For ease of discussion, the terms children and youth are broadly defined in this chapter to include the preadolescent and adolescent years. The terms older and senior have been arbitrarily defined to include men and women over 65 years of age. In this chapter, muscular strength is expressed on an absolute basis (i.e., total force measured in pounds or kilograms) or on a relative basis (i.e., ratio of absolute strength to total body mass, fat-free mass, or muscle cross-sectional area).

With the growing interest in youth resistance training, it is important for strength and conditioning professionals to understand the fundamental principles of normal growth and development. An understanding of these principles and an appreciation for how they can influence training adaptations and confound interpretation of research data are essential to the development and evaluation of safe and effective resistance training programs. Because the training of young athletes is becoming more intense and complex, anatomical and physiological factors that may be associated with acute and chronic injury also need to be considered.

The Growing Child

In this section, the terms growth, development, and maturation are used to describe changes that occur in the body throughout life. The term growth refers to an increase in body size or a particular body part; development describes the natural progression from prenatal life to adulthood; and maturation refers to the process of becoming mature and fully functional. Puberty refers to a period of time in which secondary sex characteristics develop and a child is transformed into a young adult. During puberty, changes also occur in body composition and the performance of physical skills.

Chronological Age Versus Biological Age

Because of considerable variation in the rates of growth and development, it is not particularly accurate to define a stage of maturation or develop-
ment by age in months or years, which is known as the **chronological age**. Children do not grow at a constant rate, and there are substantial inter-individual differences in physical development at any given chronological age. A group of 14-year-old children can have a height difference as great as 9 inches (23 cm) and a weight difference up to 40 pounds (18 kg). Furthermore, an 11-year-old girl may be taller and more physically skilled than an 11-year-old boy. These differences correspond to variations in the timing and magnitude of growth during puberty. The timing of puberty can vary from 8 to 13 years in girls and from 9 to 15 years in boys, with girls typically beginning puberty about two years before boys.

Stages of maturation, or pubertal development, can be better assessed by the **biological age**, which can be measured in terms of skeletal age, somatic (physique) maturity, or sexual maturation. For example, two girls on a team may have the same chronological age but differ by several years in their biological age. One girl may be sexually mature, whereas the other may not begin the process of sexual maturation for several years. In girls the onset of menstruation (**menarche**) is a marker of sexual maturation, whereas in boys the closest indicators of sexual maturity include the appearance of pubic hair, facial hair, and deepening of the voice. The assessment of maturation in children is important for several reasons. Maturity assessment can be used to evaluate growth and development patterns in children. In addition, since the degree of maturation is related to measures of fitness including muscular strength and motor skills performance (82), techniques used to assess maturation can help ensure that children are fairly matched for fitness testing and athletic competition. Although there has been concern regarding the potential negative consequences of resistance training and weightlifting on growth and maturation, there is no scientific evidence that physical training delays or accelerates growth or maturation in boys and girls (54, 94). Physical activity, specifically weight-bearing activity, actually generates compressive forces that are essential for bone formation and growth (136).

A common method of evaluating biological age was devised by Tanner (132) and involves assessing the development of identifiable secondary sex characteristics: breast development in girls, genital development in boys, and pubic hair development in both sexes. The Tanner classification has five stages: Stage 1 represents the immature, preadolescent state, and stage 5 represents full sexual maturation. Even though there can be some variation in the degree of sexual maturity of children and adolescents at a particular stage, this technique for assessing sexual maturation is often used by physicians during physical examinations.

Sensitivity to individual differences in abilities and past experiences is especially important for children in the weight room. An early-maturing 14-year-old girl may be ready to train for a sport such as weightlifting, whereas a late-maturing 14-year-old boy may not be ready for the demands of heavy resistance exercise. In addition, a child's **training age** (i.e., the length of time the child has been resistance training) can influence adaptations to resistance training; the magnitude of gain in any strength-related measure is affected by the amount of adaptation that has already occurred. For example, a 12-year-old with two years of resistance training experience (i.e., a training age of 2 years) may not achieve the same strength gains in a given period of time as a 10-year-old who has no experience resistance training (i.e., a training age of zero). Strength and conditioning professionals must recognize these differences and should individualize the training program based on each child's maturity level, training age, and specific needs.

During the period of **peak height velocity** (pubertal growth spurt), young athletes may be at increased risk for injury (102). Peak height velocity usually occurs about age 12 in females and age 14 in males. The relative weakening of the bone during this stage of growth, muscle imbalances between the flexor and extensor groups around a joint, and the relative tightening of the muscle-tendon units spanning rapidly growing bones are risk factors for overuse injuries in children. Strength and conditioning professionals may need to modify training programs (i.e., emphasize flexibility, correct muscle imbalances, or decrease the volume and intensity of training) during periods of rapid growth. If a young athlete complains of pain or discomfort during a growth spurt, the strength and conditioning professional should be suspicious of an overuse injury rather than labeling these complaints “growing pains.”
Muscle and Bone Growth

As children grow, muscle mass steadily increases throughout the developing years. At birth, approximately 25% of a child’s body weight is muscle mass, and by adulthood about 40% of a person’s total body mass is muscle. During puberty, a 10-fold increase in testosterone production in boys results in a marked increase in muscle mass, whereas in girls an increase in estrogen production causes increased body fat deposition, breast development, and widening of the hips. Although muscle mass in girls continues to increase during adolescence, the increase occurs at a slower rate than in boys due to hormonal differences. Throughout this time period the increase in muscle mass in both sexes is due to the hypertrophy of individual muscle fibers and not hyperplasia. Peak muscle mass occurs between the ages of 16 and 20 years in females and between 18 and 25 years in males unless affected by resistance exercise, diet, or both.

Bone formation occurs in the **diaphysis**, which is the central shaft of a long bone, and in the **growth cartilage**, which is located at three sites in the child: the epiphyseal (growth) plate, the joint surface, and the apophyseal insertions of muscle-tendon units. When the epiphyseal plate becomes completely ossified, the long bones stop growing. Although bones typically begin to fuse during early adolescence, girls generally achieve full bone maturity about two to three years before boys. The actual age varies considerably, but most bones are fused by the early 20s.

A particular concern in children is the vulnerability of the growth cartilage to trauma and overuse (103). Injuries there may disrupt the bone’s blood and nutrient supply and result in permanent growth disturbances. Trauma from falls or excessive repetitive stress that may result in a ligament tear in an adult may produce an epiphyseal plate fracture in a child. Because the peak incidence of epiphyseal plate fractures in children occurs at about the time of peak height velocity, it seems that a preadolescent child may be at less risk for an epiphyseal plate fracture than an adolescent child. It has been suggested that the epiphyseal plates of younger children may be stronger and more resistant to shearing-type forces, which may be the cause of injuries to the growth cartilage (105). The potential for injury to the epiphyseal plate during resistance training is discussed later in this chapter.