PHYSIOLOGICAL ADAPTATIONS TO STRENGTHENING EXERCISES

- The key elements of muscle performance are strength, power, and endurance.
- Strengthening exercise is any form of active exercise in which dynamic or static muscle contraction is resisted by an outside force applied manually or mechanically. Strengthening exercise, also referred to as resistance training,is an essential element of rehabilitation programs for persons with impaired function and an integral component of conditioning programs for those who wish to promote or maintain health and physical well-being, potentially enhance performance of motor skills, and reduce the risk of injury and disease.

BOX 6.1 Potential Benefits of Resistance Exercise

- Enhanced muscle performance: restoration, improvement or maintenance of muscle strength, power, and endurance
- Increased strength of connective tissues: tendons, ligaments, intramuscular connective tissue
- Greater bone mineral density or less bone demineralization
- Decreased stress on joints during physical activity
- Reduced risk of soft tissue injury during physical activity
- Possible improvement in capacity to repair and heal damaged soft tissues due to positive impact on tissue remodeling
- Possible improvement in balance
- Enhanced physical performance during daily living, occupational, and recreational activities
- Positive changes in body composition: ↑ lean muscle mass or ↓ body fat
- Enhanced feeling of physical well-being
- Possible improvement in perception of disability and quality of life

Physiological Adaptations to Resistance Exercise

The use of resistance exercise in rehabilitation and conditioning programs has a substantial impact on all systems of the body. Resistance training is equally important for patients with impaired muscle performance and individuals who wish to improve or maintain their level of fitness, enhance performance, or reduce the risk of injury. When body systems are exposed to a greater than usual but appropriate level of resistance in an exercise program, they initially react with a number of acute physiological responses and then later adapt—that is, body systems accommodate over time to the newly imposed physical demands.

TABLE 6.3 Physiological Adaptations to Resistance Exercise

Variable	Strength Training Adaptations	Endurance Training Adaptations
Skeletal muscle structure	Muscle fibers hypertrophy: greatest in type IIB fibers. Possible hyperplasia of muscle fibers. Fiber type composition: remodeling of type IIB to type IIA; no change in type I to type II distribution (i.e., no conversion) ↓ or no change in capillary bed density: ↓ in mitochondrial density and volume	Minimal or no muscle fiber hypertrophy ↑ in capillary bed density ↑ in mitochondrial density and volume (↑ number and size)
Neural system	Motor unit recruitment (↑ # of motor units firing) ↑ rate of firing (↓ twitch contraction time) ↑ synchronization of firing	No changes.
Metabolic system and enzymatic activity	↑ ATP and PC storage ↑ myoglobin storage Triglycerides storage: change not known ↑ creatine phosphokinase ↑ myokinase	↑ ATP and PC storage: ↑ myoglobin storage ↑ of stored triglycerides ↑ creatine phosphokinase ↑ myokinase
Body composition	↑ lean (fat-free) body mass; ↓ % body fat	No change in lean body mass; ↓ % body fat
Connective tissue	↑ tensile strength of tendons, ligaments, and connective tissue in muscle ↑ bone mineral density; no change or possible ↑ in bone mass	↑ tensile strength of tendons, ligaments, and connective tissue in muscle ↑ in bone mineralization with land-based, weight-bearing activities

Neural Adaptations

Neural adaptations are attributed to motor learning and improved coordination and include increased recruitment in the number of motor units firing as well as an increased rate and synchronization of firing. It is speculated that these changes are caused by a decrease in the inhibitory function of the central nervous system (CNS), decreased sensitivity of the Golgi tendon organ GTO), or changes at the myoneural junction of the motor unit.

Skeletal Muscle Adaptations

Hypertrophy

Hypertrophy is an increase in the size (bulk) of an individual muscle fiber caused by an increase in myofibrillar volume. After an extended period of moderate- to high-intensity resistance training, usually by 4 to 8 weeks but possibly as early as 2 to 3 weeks with very high-intensity resistance training, hypertrophy becomes an increasingly important adaptation that accounts for strength gains in muscle.

Hyperplasia

Hyperplasia is an increase in the number of muscle fibers. The general opinion in the literature is that hyperplasia either does not occur, or if it does occur to a slight degree, its impact is insignificant. In a review article published in the late 1990s, it was the authors' opinion that if hyperplasia is a valid finding, it probably accounts for a very small proportion (less than 5%) of the increase in muscle size that occurs with resistance training.

- **<u>Muscle Fiber Type Adaptation</u>**

  Type II (phasic) muscle fibers preferentially hypertrophy with heavy resistance training. In addition, a substantial degree of plasticity exists in muscle fibers with respect to contractile and metabolic properties. Transformation of type IIB to type IIA is common with endurance training, as well as during the early weeks of heavy resistance training, making the type II fibers more resistant to fatigue. There is some evidence that demonstrates type I to type II fiber type conversion in the denervated limbs of laboratory animals, in humans with spinal cord injury, and after an extended period of weightlessness associated with space flight. However, there is little to no evidence of type II to type I conversion under training conditions in rehabilitation or fitness programs.

- **<u>Vascular and Metabolic Adaptations</u>**

  Athletes who participate in heavy resistance training actually have fewer capillaries per muscle fiber than endurance athletes and even untrained individuals. Other changes associated with metabolism, such as a decrease in mitochondrial density, also occur with high- intensity resistance training. This is associated with reduced oxidative capacity of muscle.

- **<u>Adaptations of Connective Tissues</u>**

  Although the evidence is limited, it appears that the tensile strength of tendons and ligaments as well as bone increases with resistance training designed to improve the strength or power of muscles.

- **<u>Tendons, Ligaments, and Connective Tissue in Muscle</u>**

  Strength improvement in tendons probably occurs at the musculotendinous junction, whereas increased ligament strength may occur at the ligament-bone interface. It is believed that tendon and ligament tensile strength increases in response to resistance training to support the adaptive strength and size changes in muscle. The connective tissue in muscle (around muscle fibers) also thickens, giving more support to the enlarged fibers. Consequently, strong ligaments and tendons may be less prone to injury. It is also thought that noncontractile soft tissue strength may develop more rapidly with eccentric resistance training than with other types of resistance exercises.

- **<u>Bone</u>**

  Numerous sources indicate there is a high correlation between muscle strength and the level of physical activity across the life span with bone mineral density. Consequently, physical activities and exercises, particularly those performed in weightbearing positions, are typically recommended to minimize or prevent age-related bone loss. They are also prescribed to reduce the risk of fractures or improve bone density when osteopenia or osteoporosis is already present.