Chapter 6

Nerve

Purpose:
1. To describe the structure of peripheral nerves.
2. To relate nerve structure to function.
3. To describe the biomechanics of peripheral nerves.

Nervous tissue is not classified as a musculoskeletal tissue, but its function directly or indirectly affects the function of musculoskeletal tissues. For this reason a brief discussion of nervous tissue is presented. The nervous system is the body's control center and communication network. It acts to sense changes that occur within and external to the body. It interprets sensory inputs and responds accordingly. The nervous system can invoke changes in the body through muscle contractions and/or hormonal secretions.

The nervous system is generally considered to be divided into two sections: the central nervous system consisting of the brain and spinal cord, and the peripheral nervous system consisting of all the nerve processes that extend from the brain and spinal column. The peripheral nerves provide the channels for both sensory input and muscle control. Sensory input is received from the muscles, tendons, viscera, skin, and sense organs.

The peripheral nervous system contains 12 pairs of cranial nerves and 31 pairs of spinal nerves. Each spinal nerve is connected to the spinal cord through a posterior (dorsal) root and an anterior (ventral) root that unite to form the spinal nerve at the intervertebral foramen. The posterior roots contain fibers for sensory neurons, and the anterior roots contain fibers for motor neurons.

Nerve Fiber Structure:
Peripheral nerves are complex structures consisting of nerve fibers, connective tissue, and blood vessels. A peripheral nerve axon is an elongated process extending from the cell body. Sensory nerves conduct impulses from the skin, skeletal muscles, and joints to the central nervous system (CNS). Motor nerves convey impulses from the CNS to skeletal muscles.
Most axons have a myelin sheath and Schwann cells. Some small sensory nerves are not myelinated. The myelin sheath is produced by flattened cells called Schwann cells arranged around the axon. Unmyelinated gaps between Schwann cells are called nodes of Ranvier. The myelin sheath increases the nerve conduction velocity by allowing the impulses to skip from one node of Ranvier to the next. The conduction velocity of a myelinated fiber is directly proportional to the diameter of the fiber that usually ranges from 2 to 20 µm.

A nerve consists of several layers. Individual nerve fibers are located within the endoneurium. These fibers are packed into fascicles, which are surrounded by the perineurium. The perineurium is extremely strong, able to sustain pressures up to 1000 mm of mercury. The pressure within a fascicle tends to be slightly elevated compared to surrounding tissue. A bundle of fascicles is enclosed by a loose connective tissue layer called the epineurium. Blood vessels are located in all layers of the nerve.

The blood supply within a nerve is critical to nerve function. Both impulse propagation and axonal transport depend on a local oxygen supply. Thus, there tends to be an extensive blood vessel network throughout the nerve structure.

**Material Properties:**

The interaction of the nerve, connective tissue and blood vessels give rise to a nerve's mechanical properties. Nerves have considerable tensile strength. The maximum load that can be sustained by the ulnar nerve is in the range of 60 to 150 N. However, it should be noted that severe intraneural damage can occur at much lower loads than these. The tensile strength of nerve has been attributed to both the epineurium and the perineurium. Tensile testing of nerve reveals the common "toe-shape" during the application of small loads followed by a linear region as the load is increased. Failure usually begins with inner fibers and progresses outward. The maximum tensile strain that a nerve can sustain is approximately 20-30 %.

**Aging:**

Several structural and functional changes occur in peripheral nerves with aging. Most persons show some dysfunction in their nerves by the seventh decade of life. Some common changes are the loss of tactile and vibratory sensation. The conduction velocity of nerves in elderly people tends to be slightly slower compared to young adults. The structural changes underlying functional disorders that occur with aging are not completely understood.

**Injury and Repair:**

Nerves are strong structures, but they can be injured. The most common types of injury result from stretching and compression. These may occur as a result of rapid extension of the nerve or by crushing. Nerves may also be damaged by chemical, thermal, and ischemic means.

Nerves have the ability for self-repair, but the process is slow and dependent on the severity of the injury. A stretching injury may result in failure of the nerve without failure of the surrounding membranes. If this occurs than the nerve has a pathway to follow during its regeneration. Nerve regeneration is much more difficult if the entire nerve is severed and it retracts. Attempts to suture the nerve together may cause increased tension in the nerve, which may lead to blood flow occlusion and inhibition of nerve regeneration.

Nerves are very sensitive to oxygen concentrations and it appears that compression injuries may act to inhibit oxygen availability. Intermittent compressive loads may lead to scar formation which may inhibit blood flow and oxygen transport. Pressures of 30 mm of mercury
for several hours may lead to nerve impairment. The ability to recover from such injury is dependent on the damage incurred, which depends on the nerve, type of compression, duration of compression, and the type of deformation created.

After an injury in which the membranes remain intact, the distal parts of the nerve degenerate and are resorbed by macrophages. During the first week following injury Schwann cells proliferate and proximal axons start sending out a great number of sprouts which grow toward the distal end. The rate of axonal growth is about 1-3 mm per day. Repair of an injury in which the membranes are disrupted is less well organized. Regenerating axons often do not reinnervate the same organs and thus there is some central reprocessing that must occur to regain proper motor control. Nerve regeneration is greatly influenced by biochemical and biomechanical factors.

Summary:
Peripheral nerves are composed of nerve fibers, layers of connective tissue, and blood vessels. Nerve fibers are very susceptible to injury, but their connective tissue network serves to protect them during daily activities. Common nerve injuries are induced through stretching or compression. Nerves are extremely sensitive to oxygen availability. Regeneration of peripheral nerves following injury is a complex issue in which biochemical and biomechanical factors are important to the outcome. Nerve fibers grow at a maximum rate of 1-3 mm per day. Aging of peripheral nerves can result in loss of vibratory and tactile sensations as well as reduced conduction velocities.

References:

Sample Problems:
1. Please describe the functional difference between a sensory nerve and a motor nerve.
2. Please describe the basic structural organization of a nerve.
3. What differences might you expect to find between nerves in a 20 year old person and a person in his/her 80s?
4. Give two examples of situation that might cause a nerve to be injured.
5. A surgeon performs a hip replacement surgery and as part of the procedure he retracts (pull back) a large section of muscle located around the hip. During the retraction the surgeon also displaces a nerve approximately 8 cm from its normal path. If the nerve retracted innervates the tibialis anterior muscle (a dorsi flexor muscle for the ankle) do you think the nerve will sustain any ill effects due to the surgical procedure and if so what are the functional consequences? State all assumptions and provide a rationale for your conclusions.