Degeneration of articular cartilage can have a devastating effect on an individual's ability to participate in physically demanding activities. Although osteoarthritis (OA) of the knee is the most common cause of disability among older adults in the United States, its occurrence is not limited to the elderly, it is not a natural consequence of the aging process, and it is not a condition that necessarily worsens over time. OA can be regarded as a state of altered physiology that is potentially amenable to control, and reversal of the process might even be possible. The purpose of this article is to review the critical role that quadriceps strength appears to play in protecting the articular cartilage of the knee from excessive impact loading.

The composition of articular cartilage is 75–85% water, which is contained within a meshwork of hydrophilic molecules configured in a manner that resembles an aggregation of coiled wire and bottle brushes. Under a compressive load, articular cartilage behaves in a manner similar to that of a water-filled sponge, in which water is displaced to adjacent noncompressed areas and is drawn back to its original location when the compressive force is removed. Because cartilage is avascular, water translocation that results from cyclic compressive loading plays an essential role in the delivery of nutrients and removal of metabolites. Excessive loading, either a single force application of great magnitude or repetitive application of high forces, can damage the microstructural elements that give articular cartilage its resilient quality. Although damaged articular cartilage exhibits an increase in water content (as a result of the development of water-filled pockets within the damaged meshwork of microstructural elements), its ability to dissipate compressive force is compromised. Eventually, the joint surface softens, loses its smooth texture, becomes fibrillated, and develops clefts and crevices.

Magnetic resonance imaging (MRI) has dramatically increased awareness of articular cartilage pathology associated with knee-ligament injuries. Microfractures of the trabeculae of subchondral bone, which produce the appearance of an MRI “bone bruise,” are believed to heal with callus formation that decreases the compliance of subchondral bone (i.e., increases its stiffness) and concentrates force on the overlying hyaline cartilage. Complete elimination of articular-surface loading (through immobilization or restriction of weight-bearing activity) might seem logical for facilitating healing, but the absence of mechanical stimulation results in chondrocyte death. In fact, an appropriate level of cyclic compressive loading actually stimulates chondrocyte synthesis of the microstructural elements of articular cartilage. Thus, creating an optimal healing environment within articular cartilage entails careful assessment of loading tolerance. Progressive introduction of rehabilitative activities that will enhance neuromuscular dissipation of impact loads is essential to protect against potentially injurious forces.
Importance of Quadriceps Strength

The quadriceps muscle group plays an important role in preventing knee injury by restraining excessive varus or valgus knee displacement. Another extremely important role is eccentric control of knee flexion during functional activities, which attenuates the vertical component of ground-reaction force. By increasing the range of knee flexion that occurs immediately after foot contact with the ground, controlled eccentric lengthening of the quadriceps decreases the magnitude of the force impulse that would otherwise be transmitted to the articular surfaces of the knee. Prospective research findings have demonstrated that isokinetic quadriceps strength (ratio of concentric peak torque to body weight) is a strong predictor of radiographic evidence of knee OA, which has identified quadriceps weakness as a probable primary risk factor for joint degeneration.3

Loss of quadriceps strength is associated with a variety of acute knee injuries and overuse syndromes. Preinjury quadriceps strength is often exceedingly difficult to restore, particularly in patients who have an anterior cruciate ligament (ACL) deficiency or who have undergone surgical ACL reconstruction.4-10 There is clearly a widespread awareness of the importance of hamstrings strength in restraining anterior tibial translation in ACL-deficient and ACL-reconstructed patients, but there does not seem to be a high level of awareness of the importance of quadriceps strength. Isometric and isokinetic quadriceps strength in ACL-reconstructed patients have been shown to be significantly correlated with the amount of knee flexion observed during the stance phase of gait.6,10 Thus, persistent quadriceps weakness might perpetuate an abnormal gait pattern, which could have adverse long-term consequences.

Arthrogenous Muscle Inhibition

Arthrogenous muscle inhibition (AMI) is the inability to fully activate a muscle during an effort to produce a maximum voluntary contraction (MVC). Swelling of the knee-joint capsule (either pathologic or artificially produced by injection of fluid) has been clearly shown to decrease the ability to voluntarily activate the quadriceps, but AMI can also exist in the absence of swelling or pain.3,4,7,11 There is strong evidence that AMI is caused by abnormal afferent input from joint mechanoreceptors, which causes inhibitory interneurons in the spinal cord to release a neurotransmitter (gamma amino butyric acid) that decreases the excitability of the motor-neuron pool activating the quadriceps.11,12

Researchers have identified the presence of quadriceps AMI through several different methods: comparison of isometric muscle force produced by superimposition of neuromuscular stimulation (NMES) during MVC with that produced by MVC without NMES,4,7-10,12,13 decreased amplitude of the Hoffman reflex (an electrically induced muscle response that is similar to the patellar-tendon-tap reflex response),14 and decreased amplitude or decreased frequency of surface-electromyography signal during isometric MVC.6,11 Because isokinetic peak-torque generation is clearly reduced in the presence of AMI, comparison of quadriceps peak-torque values of an injured extremity with those of an uninjured extremity can provide indirect evidence that the condition exists.

Isokinetic Evaluation of Quadriceps Performance

Although some researchers have reported evidence of impaired fast-twitch-muscle performance capabilities that have been attributed to AMI, the preponderance of relevant research findings strongly suggests that slow-twitch motor units are more profoundly affected by AMI. Individuals with quadriceps AMI have been observed to increase concentric performance at 180°/s with training, whereas torque-generation capabilities remained impaired at lower isokinetic velocities (<90°/s) and with isometric testing.5,7 Furthermore, pre- and postsurgical isokinetic strength assessments of ACL-reconstructed patients have demonstrated greater bilateral deficits at 60°/s than at 120°/s.5

The effect that movement velocity appears to have on isokinetic evidence of AMI is illustrated by the data in Table 1 and the corresponding isokinetic torque curves presented in Figure 1. The patient was a 48-year-old physically active man who had experienced bilateral knee pain for several years and progressively increasing pain in his left knee over the preceding 6 months. He was diagnosed as having bilateral knee OA, with the left knee more severely affected than...