A Review of the Relationship Among Knee Effusion, Quadriceps Inhibition, and Knee Function

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Objective: To provide information on research investigating the relationship between a knee effusion and quadriceps inhibition.

Data Sources: Peer-reviewed publications from 1965 to 1997 that investigated the effect of a knee effusion on quadriceps strength.

Study Selection: The studies reviewed involved human subjects. Researchers have used active motion, electromyographic equipment, and isokinetics to measure changes in quadriceps strength after a knee effusion.

Data Synthesis: Most studies reported that a knee effusion resulted in quadriceps inhibition and inferred that quadriceps inhibition would impair knee function.

Conclusions: The authors believe that additional research is needed to better understand the effect of a knee effusion on knee function. Although a knee effusion might lead to quadriceps inhibition, other factors contribute to normal knee function and might allow enough compensation so that knee function is not affected significantly in the presence of certain effusions.

Key Words: quadriceps strength, lower extremity function, proprioception


The knee is a commonly injured joint. Sports medicine practitioners often evaluate and treat patients after a traumatic knee injury or surgical intervention. Most of these patients have an acute knee effusion that limits knee range of motion, increases pain, and decreases muscle strength. These factors lead to functional disabilities. By understanding the relationship between knee effusion, quadriceps strength, and knee function, clinicians can make better decisions with regard to when an athlete can safely return to unrestricted sporting activities. The purpose of this literature review is to summarize information on previous research aimed at explaining the physiological relationship among knee effusion, quadriceps inhibition, and knee function.

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Nerve Supply to the Knee

Nerves to the knee have both a motor and a sensory component. Hilton's law states that the nerve that supplies a joint also supplies the muscles that move the joint and the skin covering the articular insertion of these muscles. Nyland et al. and Kennedy et al. classified the knee's nerve supply into the anterior, lateral, and posterior groups. The quadriceps muscles cross the knee anteriorly, and the femoral nerve innervates this muscle group. The femoral nerve's largest terminal branch becomes the nerve to the vastus medialis and innervates the anteromedial joint capsule. The femoral nerve's terminal branch to the vastus lateralis innervates the superolateral joint capsule, the infrapatellar fat pad, and the patellar ligament. Additional neural input comes from the infrapatellar branch of the saphenous nerve, which innervates the joint capsule, patellar ligament, and skin covering the anterior aspect of the knee.

The lateral articular nerve and the recurrent peroneal nerve branch off from the common peroneal nerve. The lateral articular nerve supplies afferent neural input to the inferolateral joint capsule and the lateral collateral ligament. The recurrent peroneal nerve innervates the anterolateral joint capsule.

The posterior group nerve originates from the posterior tibial nerve, posterior articular nerve, and terminal branch of the obturator nerve. These nerves provide afferent information to the oblique popliteal ligament, the posterior joint capsule, and the outer third of the menisci. Some fibers also extend to the cruciate ligaments' synovial lining.

Sensory fibers found in skeletal muscle provide afferent information about muscle length and muscle tension, whereas those innervating the knee's structures monitor joint position, changes in direction, and rates of change. Together, sensory fibers provide feedback about muscle and joint position. Therefore, an athlete's return to functional activities (activities of daily living, as well as vocational and recreational pursuits) depends on a combination of adequate muscle strength and normal proprioception.

Proprioception

Proprioception describes awareness of posture, movement, changes in equilibrium, and mechanical inertia that generate pressures and strains at the joints. It gives kinesthetic feedback and information of knee-joint position, provides a protective reflex loop to the muscles attached to the ligaments, and relays information concerning joint pressure.

An athlete's return to functional activities depends on normal proprioception. Beard et al. reported similar findings in their investigation of 2 rehabilitation groups with anterior cruciate ligament (ACL)-deficient subjects. The first group followed a traditional strengthening program, whereas the second group followed a proprioception-enhancement protocol. The
proprioception-enhancement group, having achieved greater functional outcomes, demonstrated a positive correlation between an individual’s return to functional activities and proprioception.

Mechanoreceptors gather and submit information used in maintaining proprioception, and researchers have identified the 4 types of mechanoreceptors in the knee’s structures. According to Nyland et al., type I Ruffini mechanoreceptors, which lie superficially within the joint capsule, adapt slowly to changes in static joint position, intra-articular pressure changes, and joint kinematics. On the other hand, type II Pacinian mechanoreceptors adapt rapidly to changes in dynamic position. Type III mechanoreceptors react in a manner similar to that of the Golgi tendons found in muscles and provide information at extremes of joint motion, such as excessive knee flexion or extension. Type IV receptors represent free nerve endings that relay information on pain and inflammation.

As mentioned previously, mechanoreceptors transmit afferent discharges. Researchers believe that an effusion distends the knee joint capsule; mechanoreceptor stimulation creates afferent nerve impulses that promote muscle inhibition. Iles et al. believe that mechanoreceptor stimulation causes muscle inhibition, partly through the Ib inhibitory pathway. In fact, silencing the mechanoreceptors with a local anesthetic decreases muscle inhibition. Because quadriceps inhibition most commonly affects knee function, the next section discusses other explanations for this phenomenon.

Quadriceps Inhibition

Arthrogenous muscle weakness is weakness of muscles acting about an injured or inflamed joint resulting from reflex inhibition of quadriceps’ motor neurons. Patients having experienced a knee injury or surgical intervention generally have a joint effusion. The effusion leads to the quadriceps’ inability to generate a strong contraction, because the excess fluid reduces the excitability of the motoneuron pool needed for a muscle contraction.

One can assess the decrease in the excitability of the motoneuron pool by measuring the Hoffmann (H) reflex. The H reflex is an electrically evoked monosynaptic stretch reflex produced by low-voltage stimulation of the femoral nerve. A reduction in the H reflex indicates inhibitory action from knee-joint afferents on the quadriceps’ motor neurons. Young believed that various factors contribute to inhibition of the anterior horn cells. These factors include joint inflammation, elevated joint tension, loss of afferent input via rupture of the anterior cruciate ligament, decreased descending tonic inhibition, and reciprocal inhibition. Most research has focused on the relationship between quadriceps inhibition and knee-joint effusion.

Relationship Between Knee Effusion and Joint Pressure

Pressure of synovial fluid in a healthy knee generally is a few mmHg below atmospheric pressure (760 mmHg). Increases in pressure interfere with
Knee Effusion, Joint Pressure, and Quadriceps Inhibition

Researchers have performed various studies to quantify the relationship between knee effusion, joint pressure, and quadriceps inhibition in both normal and acutely effused knees. de Andrade et al. were the first researchers to study the relationship between knee effusion and quadriceps inhibition in human subjects. They had each subject lie supine, with the tested knee supported by a towel roll at 10° of flexion. They infused the knee joint with pooled human plasma in increments of 10 ml. These researchers measured joint pressure using a strain-gauge transducer and electronic recorder. They intermittently measured quadriceps strength by having each subject lift his or her heel from the table, and they defined quadriceps inhibition as the point at which the subject could no longer perform a heel lift. Their study indicated a positive linear relationship between articular pressure and infused plasma volume, as later described by Levick.

Spencer et al. also infused saline into the knee joint of healthy subjects, but they measured changes in the H reflex in determining quadriceps inhibition. Specifically, Spencer et al. infused saline in increments of 10 ml up to a maximum of 60 ml. They evoked H reflexes by percutaneous electrical stimulation of the femoral nerve and recorded intracapsular pressures at each increment. Results showed a significant reduction in the H-reflex amplitude with joint distention. Based on this method, Spencer et al. concluded that quadriceps inhibition occurred between 20 and 30 ml of saline injection, further supporting the fact that a trace effusion can affect knee function. Kennedy et al. reported similar findings with their study measuring the H reflex; however, they only measured the H reflex after a 60-ml infusion.

Other investigators have researched quadriceps inhibition using electromyographic (EMG) studies. For example, Stratford recorded rectus femoris, vastus lateralis, and vastus medialis EMG activity in both normal and acutely effused knees at 30 and 0° knee flexion. The researcher measured each subject performing a maximal isometric contraction for 6 seconds. The normal group had no difference in EMG activity; however, the acutely effused group demonstrated a significant decrease in EMG activity.
at both 30 and 0° knee flexion. Furthermore, the subjects in the acutely effused group had more decreased EMG activity at 0° of flexion than at 30° because of the increased joint pressure at full extension.

Fahrer et al. reported similar findings in their study of patients with chronic effusions. This group measured EMG activity at 60° knee flexion and recorded isometric quadriceps strength both before and after joint aspiration. Their results showed a 13.6% strength increase after joint aspiration.

Jensen and Graf studied the relationship among knee effusion, intra-articular pressure, and quadriceps inhibition through the knee’s full arc of motion. They studied 12 subjects with normal knees using a Biodex Multijoint Isokinetic testing system at 60°/s and recorded quadriceps torque at 90, 50, and 15° of flexion, as well as peak torque. They measured the experimental group at effusion levels of 0, 20, 40, and 60 ml. They found that quadriceps strength decreased and intra-articular pressure increased as the acutely effused knee actively worked. Their results differed from those of Spencer et al. because Jensen and Graf found significant changes in quadriceps strength between 40 and 60 ml of effusion; however, these high levels might be attributable to absorption of the saline into the knee joint during exercise. Although this study attempted to correlate knee function to joint effusion, the findings did not make it possible to directly extrapolate the results in order to predict the effect that a simulated knee effusion has on quadriceps function during sporting activity. Based on the Jensen study, future research should investigate the relationship between a knee effusion and knee function with the subjects performing activities involving running, jumping, and other sport-specific drills.

### Knee Effusion and Proprioception

The previously described studies investigated the relationship between an acute knee joint effusion and quadriceps inhibition. The researchers assumed that quadriceps inhibition would result in decreased knee performance. Although quadriceps strength is an important component, other factors contribute significantly to normal knee function, including proprioception, neuromuscular coordination, and other muscular cocontractions.

One of the first researchers to assess proprioception, Barrett studied 45 patients who had undergone ACL reconstruction. Initially, each subject completed both a functional assessment and a satisfaction questionnaire. Then, using a modified Thomas splint with a Pearson passive knee-flexion piece, Barrett tested proprioception by having the subject lie supine, with the affected leg supported in the splint, and passively moved the knee to 10 different flexion positions. The subjects indicated their perception of the knee-flexion angle on an analog model that incorporated a goniometer. Barrett defined proprioceptive accuracy as the difference between the perceived flexion angle and the actual angle measured with a goniometer. He
found that the proprioception measurement correlated well with patient satisfaction and function. Successful ACL reconstruction might not necessarily depend directly on ligament tightness or strength but rather on the quality of proprioceptive recovery.\textsuperscript{15}

Although many researchers have reported on the relationship between acute knee effusions and quadriceps inhibition,\textsuperscript{1,3,4,6,7,10,24} McNair et al\textsuperscript{25} investigated the effects of an acute effusion on proprioception in an open chain activity. Using 2 groups of normal knees, they placed each subject in an isokinetic machine that passively moved the limb from 10 to 90° knee flexion at 60°/s. They then blindfolded each subject and had each participant actively track the passively moving joint with the uninvolved knee for 1.25 minutes. After the initial track, the researchers injected 90 ml of saline and dextrose into 10 knee cavities. The experimental-group subjects then moved the knee until each regained normal range of motion and repeated the tracking test. The noninjected group also performed the test again. These authors measured proprioception as the difference between the signals of the passive and active limbs. There was no significant statistical difference between trials within either group. The injected fluid did not decrease proprioceptive performance in subjects with healthy knees. A limitation of this study was that open chain activities might not directly correlate to lower extremity function.

Andersen et al\textsuperscript{26} investigated the reproducibility of a knee-joint flexion angle in both open and closed chain activity in normal knees. These clinicians had subjects with healthy knees reproduce knee-flexion angles at 15, 45, and 75° in both open and closed chain positions and found that subjects more accurately reproduced the designated flexion angle in the closed kinetic chain position. Even though the study of Andersen et al\textsuperscript{26} reported on the importance of proprioception in a closed chain position, it did not investigate changes that could occur in the presence of a knee effusion. Future research projects exploring the relationship between an effusion and proprioception during more functional activities would provide important information concerning knee function.

### Implications for Future Research

A minimal effusion can cause physiological changes in the knee joint that could lead to quadriceps inhibition.\textsuperscript{7} Many researchers have reported on the effects of a simulated knee effusion on quadriceps strength and have made generalizations that such strength changes would affect lower extremity function.\textsuperscript{1,3,4,6,7,10,24}

Although knee function depends on adequate quadriceps strength, merely stating that quadriceps inhibition results in decreased lower extremity function might be oversimplifying. Lower extremity function requires coordinated activity of various muscles crossing multiple joints. In assessing lower extremity function, clinicians often use the single-leg hop-
for-distance tests. These tests assess lower extremity function in a way that other muscle groups such as the hamstrings and triceps surae might contribute to lower extremity function. There has been a statistically significant relationship shown between quadriceps isokinetic strength and the single-leg hop test; however, Pincivero et al found a stronger correlation between isokinetic hamstring strength and the single-leg hop. This study suggested that changes in quadriceps strength alone do not necessarily result in decreased lower extremity function.

Many studies have investigated the relationship between a simulated effusion and quadriceps strength with the knee in a static position. Functional activities, such as the single-leg hop for distance, require athletes to use the knee through various ranges of motion. McNair et al believed that fluid movement from a concentrated area of the joint to other compartments would cause decreased stress on the joint capsule and decrease mechanoreceptor activity. This fluid movement would result in reduced pressure and a decrease in quadriceps inhibition. McNair et al raised the question that quadriceps inhibition might not have occurred at as low a level of simulated effusion as previously thought. The purpose of our article is not to refute previous researchers’ findings but merely to suggest that future research is needed to better define and measure the effect of a simulated knee effusion on quadriceps strength and, more important, on lower extremity function.

Summary

Sports medicine practitioners often evaluate and treat patients after a knee injury or surgery. These patients often have a knee effusion that results in decreased knee function. Clinicians must clearly understand the physiological changes that an effusion produces on the knee joint in order to properly evaluate the athlete and design the most appropriate rehabilitation program. By understanding these changes, clinicians can more efficiently help patients achieve the goals needed for a safe return to sporting activities.

References


