The extensor mechanism of the knee includes the four muscles of the quadriceps, the patella, the patellar tendon, all the soft tissues attaching to the patella, and the tibial tuberosity (Gressamer & McConnell, 1998). It is involved with almost any functional activity of the lower extremity. Disorders of the extensor mechanism are some of the most common conditions presenting to clinicians managing sports injuries. Although the incidence of these disorders is high, the diagnosis and treatment are often difficult. The purpose of this article is to discuss the anatomy and biomechanics of the extensor mechanism. Hopefully, this knowledge will help athletic trainers and therapists diagnose and treat these disorders.

**Quadriceps Muscles**

The dynamic structures of the extensor mechanism are the quadriceps muscles. The quadriceps consists of the rectus femoris, the vastus intermedius, the vastus lateralis, and the vastus medialis (Williams & Warwick, 1980). The vastus medialis can be divided into two portions: the vastus medialis longus and the vastus medialis obliquus (Figure 1).

The rectus femoris originates from the anterior inferior iliac spine and groove superior to the acetabulum and inserts into the quadriceps tendon. The fibers of the rectus femoris are oriented about 5° relative to the long axis of the femur. It is the only one of the quadriceps muscles to cross the hip joint, giving the hip joint some importance with respect to the extensor mechanism. A shortened rectus femoris might inhibit full excursion of the patella on the trochlea as the knee flexes, particularly when the hip is extended (McConnell, 1986).

The vastus intermedius originates from the anterior and lateral surfaces of the body of the femur and inserts into the quadriceps tendon. The direction of pull of the vastus intermedius is along the line of the femur. It functions as the most efficient extensor, requiring less force to extend the knee than do the other parts of the quadriceps (Lieb & Perry, 1968).

The vastus lateralis originates from the greater trochanter and lateral lip of the linea aspera of the femur. It inserts anteriorly into the quadriceps tendon and laterally into the lateral retinaculum. The fibers of the vastus lateralis are oriented 20 to 40° relative to the long axis of the femur, with the distal fibers more obliquely oriented than the proximal fibers.

The vastus medialis longus originates from the intertrochanteric line and medial lip of the linea aspera of the femur and inserts anteriorly into the quadriceps tendon. The fibers of the vastus medialis longus are oriented 15 to 18° relative to the long axis of the femur.
The quadriceps muscles function as extensors of the leg in the open kinetic chain (OKC) and as decelerators of the leg in the closed kinetic chain (CKC). During OKC knee extension, the flexion moment arm increases as the leg moves into extension, requiring the quadriceps force to increase as the knee extends. During CKC exercise, the flexion moment arm increases as the leg moves into flexion, requiring the quadriceps force to increase as the knee flexes.

The VMO, although active during leg extension, is not capable of performing independent extension of the leg. The VMO is the primary dynamic stabilizer of the patella, helping keep it centered in the trochlea of the femur. The centered position provided by the VMO enhances the efficiency of the quadriceps during knee extension. Historically, treatment of patellofemoral pain has focused on strengthening the VMO to improve dynamic patellar stability. However, there is no conclusive evidence that specific exercises can be performed to selectively recruit the VMO (Powers, 1998).

**Quadriceps Tendon**

The quadriceps tendon is formed by the convergence of the quadriceps muscles. The tendon is composed of three layers that insert into the patella (Williams & Warwick, 1980). The superficial layer contains the rectus femoris, which inserts into the superior pole and superior third of the anterior surface of the patella. The intermediate layer contains the vastus lateralis and vastus medialis and inserts into the base of the patella posterior to the rectus femoris. The deep layer contains the vastus intermedius, which inserts into the base of the patella posterior to the other layers but anterior to the capsule.

**The Patellar Ligament and Tibial Tuberosity**

The patellar ligament is a strong, thick band, which is really a continuation of the quadriceps tendon and is often called the patellar tendon. It originates at the inferior pole of the patella and inserts onto the tibial tuberosity (Williams & Warwick, 1980). The superior part of the ligament overlies the infrapatellar fat pad, and the inferior part overlies the deep infrapatellar bursa. The central third of the patellar tendon is currently the
"gold standard" for knee-ligament reconstruction because of the ultimate strength to failure and bone-to-bone fixation that it affords. It is common to have problems with the extensor mechanism after ligament reconstruction using an autogenous patellar tendon graft.

The prominence onto which the patellar ligament attaches distally is the tibial tuberosity. It usually lies just lateral to the midline of the tibia. In childhood and adolescence, it is separated from the tibial shaft by a growth plate. Because the growth plate does not contribute to the overall length of the bone, it is called an apophyseal rather than an epiphyseal plate (Gressamer & McConnell, 1998).

The Medial Retinaculum and Ligaments

The medial retinaculum consists of the fibrous expansion from the VMO and quadriceps tendon and inserts into the superior medial border of the patella. It is thinner than the lateral retinaculum and does not provide any significant restraint to lateral patellar translation.

Beneath the medial retinaculum are the patellocoronal, patellomeniscal, and patelloitibial ligaments (Conlan, Garth, & Lemons, 1993). The medial patellofemoral ligament extends from the medial femoral epicondyle and adductor tubercle to the superior medial border of the patella. The medial patellomeniscal ligament inserts on the inferior portion of the patella and the anterior portion of the medial meniscus. The medial patelloitibial ligament runs from the inferior medial edge of the patella and inserts approximately 1.5 cm below the joint line of the tibia. The medial patellofemoral ligament is the primary passive restraint to lateral patella displacement, contributing 60% of the total restraining force (Desio, Burks, & Bachus, 1986).

Plicae

A plica is described as a fold of the synovium of the knee and is present in 20–60% of the population (Blackburn, Eiland, & Bandy, 1982). The plicae commonly described are (a) the suprapatellar plica, which runs from the lateral patellar tendon to the medial wall of the knee joint; (b) the medial patellar plica, which runs from the medial wall of the knee to the infrapatellar fat pad; and (c) the infrapatellar plica, which extends from the intercondylar notch to the infrapatellar fat pad. The plicae are usually asymptomatic but can become symptomatic as a result of trauma, chronic overuse, or some other pathologic condition that causes chronic or recurrent inflammation.

The Patella

The patella is a sesamoid bone located within the extensor mechanism. It is triangular in shape, with its base directed superiorly and its apex inferiortly. The posterior surface is divided into a medial and a lateral facet by a central ridge. The most medial portion of the medial facet is known as the odd facet.
The articular cartilage on its posterior aspect is the thickest in the body and functions to attenuate the extremely high stresses placed on the patella during daily activity. The patella serves to centralize the divergent forces of the quadriceps and increase the extensor moment arm of the extensor mechanism.

Only part of the patella articulates with the femoral trochlea at any given time. In full extension the patella is not in contact with the distal femur but sits above the trochlear groove without significant compressive load. Initial contact between the distal portion of the patella and the trochlea occurs between 10 and 20° of flexion. The contact area moves proximally as the knee flexes so that by 90° of flexion the superior part of the patella contacts the trochlea. Beyond 90° of flexion the patella rides down into the intercondylar notch, and the quadriceps tendon articulates with the trochlear groove of the femur. It is not until the end range of flexion that the odd facet of the patella makes contact with the medial femoral condyle (Goodfellow, Hungerford, & Zindel, 1976; Figure 2).

**Patellofemoral Joint-Reaction Forces**

The patellofemoral joint-reaction force (PFJRF) is a measure of compression of the patella against the femur (Figure 3). The magnitude of this force depends on the quadriceps/patellar-tendon tension and the angle of knee flexion. In CKC exercises the PFJRF increases as the knee flexes. This is a result of the angle between the quadriceps tendon and patellar tendon becoming more acute and the increasing quadriceps force produced during flexion of the knee. During level walking, the PFJRF is half of body weight, when ascending and descending stairs the force is 3 to 4 times body weight, and during squatting it is 7 to 8 times body weight (Reilly & Martens, 1972).

In OKC exercises the PFJRF increases as the knee extends from a flexed position. This is a result of the increasing quadriceps force produced during extension of the knee. During knee extension against a 9-kg weight, the peak PFJRF is 1.4 times body weight at 36° of flexion (Reilly & Martens, 1972).

**Patellofemoral Contact Stress**

The patellofemoral contact stress is determined by dividing the PFJRF by the patellofemoral contact area. The contact stress is an important consideration when prescribing exercises for the knee. OKC and CKC exercises produce different amounts of contact stress on the patellofemoral joint. During CKC exercise the PFJRF increases as the knee flexes. The patellofemoral contact area also increases, but the change is less than that of the PFJRF. Therefore, the contact stress increases as the knee goes from 0 to 90°.

During OKC exercise the PFJRF increases, and the patellofemoral contact area progressively decreases as the knee extends. Therefore, the patella has less contact area to disperse the increasing PFJRF, resulting in large contact stresses. This increase in contact stress occurs until approximately 20° of flexion, when the patella no longer contacts the trochlea.

Both OKC and CKC exercises can be incorporated into a treatment program for patients with dysfunction of the extensor mechanism. CKC exercises produce relatively low joint-reaction forces and contact stress from 0 to 45° of knee flexion. In this range, suggested CKC exercises include step-ups, minisquats, and leg presses. OKC exercises produce relatively low

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joint-reaction forces and contact stress from 50° to full flexion and from 10 to 0° of knee flexion. In these ranges, suggested exercises include short-arc isotonics, multiangle isometrics, straight-leg raises, and quadriceps sets. The range in which these exercises are performed can be modified based on the location of chondral lesions and patient symptoms.

**Determining Patellar Alignment**

Malalignment of the patella is commonly regarded as a contributing factor to dysfunction of the extensor mechanism (Fulkerson, 1997). A number of measures are used to assess patellar alignment, including the quadriceps angle (Q angle) and the A angle.

The Q angle is the intersection of a line drawn from the anterior superior iliac spine to the midpoint of the patella and a line drawn from the tibial tuberosity to the midpoint of the patella (Hungerford & Barry, 1979). This angle estimates the resultant force vector between the quadriceps muscle and the patellar tendon. The normal Q angle is reported to be 10° for men and 15° for women when the knee is extended and the quadriceps relaxed (Hungerford & Barry). An increase in Q angle can be caused by lateral displacement of the tibial tuberosity, increased femoral anteversion, genu valgum, external tibial torsion, or abnormal pronation of the foot. An increased Q angle predisposes the patella to lateral deviation as the quadriceps contracts. Although the Q angle is a standard measure for identifying patellar alignment, its significance as a clinical measure has been questioned. One recent study investigated the relationship between Q angle and anterior knee pain. The results revealed minimal differences in the magnitude of the Q angle between subjects who were symptomatic and those who were asymptomatic, indicating that the Q angle alone might not be sufficient to identify pathological conditions (Caylor, Fites, & Worrell, 1993).

The A angle is a method of measuring patellar alignment by relating position of the patella to the tibial tuberosity. It is defined as the complement of an angle that longitudinally bisects the patella and a line from the tibial tubercle to the apex of the patellar inferior pole (Arnold, 1990). The measure was originally described as a means of assessing patella alignment...
glide, tilt, and rotation. A subsequent study demonstrated poor reliability for measurement of the A angle with calipers (Ehrat, Edwards, Hastings, & Worrell, 1994).

Effect of Lower Extremity Mechanics

There are many reports in the literature that correlate poor foot alignment with dysfunction of the lower extremity (Shelton & Thigpen, 1991). Many of these reports link abnormalities in the subtalar joint to knee pain (James, Bates, & Osternig, 1978). Abnormal pronation of the subtalar joint results in increased internal rotation of the lower leg because of the anatomic congruency of the talus within the ankle mortise. The increased tibial rotation produces a compensatory femoral internal rotation that can alter the normal tracking of the patella by increasing the functional Q angle (Tiberio, 1987). Some common causes of abnormal pronation are varus deformities of the foot and inadequate dorsiflexion of the ankle. In one study of adolescent boys (McConnell, 1986), subtalar pronation, not Q angle, was found to be the single most significant predictor of patellofemoral pain. Thus, a thorough biomechanical examination of the lower extremity might be necessary when examining a patient with knee pain.

Summary

The anatomy and biomechanics of the extensor mechanism have been reviewed. A thorough understanding of the anatomy and biomechanics can help athletic trainers and therapists diagnose and treat the extensor mechanism. When applied to the rehabilitation process, this knowledge can maximize patient function while minimizing the risk of further symptoms or injury.

References


Captain Gerald McgInty earned a bachelor’s degree in physical therapy from the University of Maryland in 1988 and an advanced master’s in orthopedics from the University of Pittsburgh in 1999. He is currently the chief of physical therapy at Keesler Air Force Base in Biloxi, MS.

James Irgang serves as vice chairman for clinical services and assistant professor in the Department of Physical Therapy at the University of Pittsburgh School of Health and Rehabilitation Sciences. In addition, he is vice president of quality improvement and outcomes for the Centers for Rehab Services, which is the clinical rehabilitation service arm affiliated with the University of Pittsburgh Medical Center.