### Exercise name
(Home or studio stretching)

**Muscle group:** Knee flexors

**Muscles emphasized:** Hamstrings

**Joint position:** Knee extension with hip flexion

**C. Standing hamstring stretch**  
(Static)

<table>
<thead>
<tr>
<th>Description</th>
<th>Progression</th>
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<tbody>
<tr>
<td>Stand on one leg with the other leg lifted to the front while the ankle is supported on a barre, chair, or box. While maintaining a straight knee, lean the torso over the outstretched leg until a moderate stretch is felt along the back of the knee or back of the thigh. (Tighten quadriceps if necessary to maintain the knee in a fully straight but not hyperextended position; lean the torso forward by flexing at the hip while keeping the upper back extended versus rounded forward.)</td>
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| 1. Gradually increase the height of the object that supports the outstretched leg.  
2. Bring the torso closer to the front leg. |

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Patella on the back leg (figure 5.30A). However, this stretch is often inappropriate for more beginning-level or tight dancers, in whom inadequate flexibility necessitates an uncomfortable position in which the weight is borne on the patella (figure 5.30B). In such instances, alternatives such as performing the lunge stretch without bringing the heel to the buttocks (with the lower leg on or off the floor; figure 5.30C) or substituting a prone, side-lying, or standing position (figure 5.30D) are advised.

### Knee Flexor Stretches

When the hip is flexed as in a front développé, lack of adequate hamstring flexibility can limit the ability to fully straighten the knee. Because the hamstrings also cross the hip, stretches for these muscles were described in connection with the hip in chapter 4. However, there are other times when the hip is not flexed that some dancers may not be able to fully straighten their knees. This may be due to structural factors such as the angle between the tibia and femur, as well as soft tissue restraints such as the ligaments and capsule listed in table 5.4, and the prudence of stretching such structures is controversial. Hence, it is important that such dancers see an orthopedist to determine their restraints and whether it is advisable for them to stretch the knee. However, if not contraindicated, very careful, gentle, and consistent stretching of the knee such as using the standing hamstring stretch (table 5.5C) can often result in gradual improvement (often taking months or a year to achieve a "straight" look). Because the structures being stretched are not primarily muscular, stretches should be done with particular care when the body is adequately warmed, avoiding excessive force or pain that can result in injury.

### Knee Injuries in Dancers

The fact that the knee joint is located between the longest bones of the body and that, although broad, it is a very shallow articulation, leaves it very vulnerable to valgus and varus stresses with resultant potential injuries to the ligaments and menisci. This potential vulnerability is further heightened by the rotation allowed at the knee when it is in a flexed
Screening Test for Quadriceps Femoris Flexibility

While the dancer is lying prone, the examiner applies light pressure on the ankle to bring one heel toward the buttocks as shown in the figure. Stop if any pain is experienced. The dancer should focus on using the abdominal muscles to prevent the pelvis from anteriorly tilting throughout the test. The goal is to be able to easily bring the heel to the buttocks with the foot relaxed, but if they cannot be easily approximated, the examiner uses a ruler to measure the distance between the heel and the buttocks while maintaining light pressure. Holding the ankle at a right angle makes the test more challenging, but some dancers will be stopped by approximation of the posterior thigh and calf muscles versus quadriceps tightness with this test variation.

Position. Anteriorly, the quadriceps, patella, and patellar tendon (collectively termed the extensor mechanism) serve key antigravity, deceleration, acceleration, and stability functions and also can be readily involved in both acute and chronic injuries.

With this general injury vulnerability and the large demands placed on the knee with jumping, floor work, and repetitive flexion, it is not surprising that knee injuries are common in dancers. The percentage of total injuries involving the knee has been reported as 16.1% to 17.3% for ballet dancers (Garriick, 1999; Quirk, 1987) and 14.5% to 18% for dancers at performing arts schools (Rovere et al., 1983; Wiesler et al., 1996). A survey of modern dancers revealed the knee was the most commonly reported site of injury with 20.1% of dancers reporting injury to this area (Solomon and Micheli, 1986), while a survey of Broadway dancers found 15% of dancers reported sustaining an injury to the knee during their production (Evans, Evans, and Carvajal, 1996).

Prevention of Knee Injuries

Given that the absolute strength of the quadriceps in some dancers may be lower than desirable and that low thigh power production tends to be linked with greater severity of lower extremity injuries (Koutedakis et al., 1997), many dancers would benefit from including supplemental quadriceps and hamstring strengthening (the latter for balance) in their regular training regimes. In addition to isolation exercises, this training would also ideally include exercises aimed at developing functional strength, such as jumping drills, in which proprioception and neuromuscular skills could be developed in movements commonly associated with injury. One study showed that a program utilizing bounding drills (plyometric training) reduced ACL injury to almost one-third of that seen in untrained athletes (Hewett et al., 1999).

Adequate flexibility of the quadriceps and paying close attention to technique may also help reduce
FIGURE 5.30  Low lunge quadriceps stretch. (A) Flexible dancer with weight on the thigh above the kneecap, (B) tighter dancer with weight on the kneecap, (C) alternate hip flexor stretch, (D) alternate quadriceps stretch.
injury risk. In terms of technique, excessive twisting of the tibia relative to the femur, inadequate stabilization of turnout from the hip, letting the knees "fall in" relative to the feet, overuse of the quadriceps, or excessive foot pronation can put undue stress on the knee and may increase the risk for certain types of knee injuries.

**Common Types of Knee Injuries in Dancers**

Many different types of injuries can occur around the knee. A discussion of a few of these injuries that more commonly occur in dancers follows, and interested dancers are referred to the publications written by James Garrick (1989, 1999), Ronald Quirk (1987), and other authors cited in this section for a more detailed presentation of knee injuries.

**Knee Ligamental Injuries**

Serious ligamental injuries to the knee are very common in skiing and contact sports. Although they are less common in dance, when they do occur they can severely affect the dancer's ability to dance, and prompt medical treatment is essential. With youth, particular care must be taken that adequate medical treatment be obtained, since the ligaments of the knee are generally stronger than the growth plates and injury to a ligament may also involve epiphyseal injury.

The ligaments are key to the stability of the knee, so when a ligament is torn, knee stability is temporarily jeopardized. The two most commonly involved ligaments in dancers are the medial collateral ligament and the ACL. Dancers with extreme generalized joint mobility (hypermobility) are probably more vulnerable to such ligamental injury.

**Medial Collateral Ligament Injury** The most commonly occurring ligamental injury in sport involves the medial collateral ligament (Gaillet, 1996). Such injuries often result from a medially directed force against the lateral side of the knee (valgus-deforming force) that tends to open up the inside of the knee as seen in figure 5.31. In dance, this type of force can occur when a dancer falls on another, as may happen, for example, in contact improvisation. Noncontact injuries of the medial collateral ligament may also result from deceleration, pivoting, or forcing turnout and pushing the knee forward relative to the foot, such as in fifth-position turned-out pliés (Quirk, 1988). It appears that the medial collateral ligament is particularly vulnerable to twisting of the tibia externally (Hall, 1999).

Symptoms of this injury include pain on the inside of the knee where the medial collateral ligament is located. When the ligament is palpated, tenderness and swelling are commonly present. Tests performed by the physician that are designed to stress this ligament (see Tests and Measurements 5.1 on p. 242) will also generally be positive.

Treatment will vary greatly depending on the severity of the ligament sprain and the approach of the attending physician. More serious sprains may involve initial bracing or immobilization and use of crutches or a cane for locomotion (Diduch, Scuderi, and Scott, 1997; Mercier, 1995), while less serious sprains may require only temporary limitation of specific dance movements such as fifth position. Quadriceps strengthening, and later strengthening of the other muscles that cross the knee, are instituted, with care taken to use positions and ranges of motion that are pain free and that avoid undue valgus stress. With its location outside of the joint (extra-articular), this ligament has good healing capacity (Scioscia, Giffin, and Fu, 2001). Hence, recovery from tears of the medial collateral ligament with conservative treatment tends to be excellent, with a very good prognosis for future full return to dance.

**Anterior Cruciate Ligament Injury** One of the most dreaded injuries for the dancer is rupture of the ACL as seen in figure 5.32. Anterior cruciate injury occurs most frequently in sports that involve deceleration, twisting, pivoting, and jumping—all motions that occur in dance. Females appear to
have a markedly greater incidence of anterior cruciate tears than males in competitive sport; different sources estimate two to seven times greater risk in females (Diduch, Scuderi, and Scott, 1997; Ireland, 2000; Scioscia, Giffin, and Fu, 2001). This increased incidence in females has been attributed to the shape and size of the femoral notch, less muscular development, greater ligamental laxity, less developed proprioception, greater hamstring flexibility that may lessen the hamstrings’ potential protective effect on the ligament, and anatomical alignment tending to create a greater Q angle (Boden, Griffin, and Garrett, 2000; Scioscia, Giffin, and Fu, 2001).

A common mechanism for injury to this ligament in contact sports is a blow to the lateral knee that includes external rotation. In noncontact ACL injury, a common position on landing involves the body's falling such that the hip is adducting and internally rotating, with the knee collapsing into valgus while the tibia translates forward from an externally rotated position. This position is termed “the position of no return” and is shown in figure 5.32B. The most prevalent mechanism of injury in modern, ballet, and jazz dance appears to be landing in hyperextension from a jump on one leg as shown in figure 5.32C (Liederbach and Dilgen, 1998).

Classically the dancer feels a “pop” and is unable to continue dancing at the time of ligament injury. The knee generally feels unsteady, with significant pain and ensuing rapid swelling. However, because ligaments themselves do not generally contain pain receptors, the degree of pain is not necessarily a good indicator of the degree of injury, and dancers should seek medical evaluation if instability is present, even if pain is limited. Tests performed by the physician that are designed to test integrity of this ligament, including the anterior drawer test (Tests and Measurements 5.1C on p. 242), will generally be positive, and some orthopedists will utilize equipment to measure the exact anterior displacement of the tibia allowed on the injured side in comparison to the uninjured side.

Recommended treatment for minor anterior cruciate injuries may involve initial immobilization in a compression dressing with ice and elevation followed by hamstrings and quadriceps strengthening (Mercier, 1995). However, if the rupture is complete, this is one injury for which early surgical repair is often recommended for active individuals. Dancers with anterior cruciate deficient knees will often describe their knee as separating or “going out” (e.g., tibia sliding forward and then coming back) with movements such as walking down stairs. Repeated episodes of instability may cause further instability, injury to the menisci, and joint surface degeneration (Evans, Chew, and Stanish, 2001; Suter and Herzog, 2000). Hence, surgery to improve stability and joint function is often recommended, and Weiker (1988) holds that surgical repair of an ACL tear offers an 85% to 95% chance of being able to continue a professional dance career in contrast to only a 25% to 30% chance without surgery.

The ACL tends to heal poorly because it is located within the joint (intra-articular), where joint fluid
Interferes with fibrin clot formation essential for the healing process (Scioscia, Giffin, and Fu, 2001). So, reconstruction rather than repair of the torn ligament is often the treatment of choice with dancers. One commonly used method utilizes a graft taken from the central one-third of the patellar tendon of the injured dancer (including a bony block from the tibial tuberosity and another from the patella), which is then fixed to the tibia and femur. Another method utilizes a graft taken from the injured dancer's medial hamstrings.

Whether a surgical or conservative approach is taken, the dancer should seek rehabilitative treatment from a qualified physical therapist who is working closely with the attending physician. Open kinematic chain knee extension exercises such as terminal extension can place large stresses on the ACL that may cause damage to an injured or reconstructed ligament. Hence, there are specific recommendations regarding the appropriate range of motion, appropriate use of open and closed kinematic chain exercises, and loading of the joint in different phases of rehabilitation that must be closely followed. Also, unlike what occurs with many other injuries, hamstring strength is particularly emphasized, as the hamstrings can pull the tibia posteriorly, aiding the anterior cruciate in its function. Long-term rehabilitation goals for anterior cruciate as well as other knee injuries are to maximize dynamic stability of the knee and prepare it to function with the diverse loading presented with dance training (Boden, Griffin, and Garrett, 2000; Brown and Clippinger, 1996; Irrgang, 1993; Loosli and Herold, 1992).

Meniscal Injury

The meniscus is designed to move with the tibia on the femur in a well-coordinated manner. However, if this coordinated movement becomes disrupted, the meniscus can become trapped between the opposing articular surfaces of the tibia and femur with resultant injury from compression, torque, or traction. The meniscus can be split, broken into pieces, or loosened by tearing of its ligamentous attachments. The medial meniscus has been reported to be torn 10 (Mercier, 1995) to 20 times (Caillet, 1996) more frequently than the lateral in general populations. One study of dancers also showed a predominance of medial meniscus tears, with 13 of the 15 meniscal tears examined arthroscopically involving the medial meniscus (Silver and Campbell, 1985). This increased vulnerability of the medial meniscus is probably related to its reduced mobility due to its attachment to the medial collateral ligament and joint capsule.

One of the most common mechanisms of injury of the meniscus is extension from a flexed, abducted position of the knee (valgus stress) while the leg is externally rotated with the foot fixed. In contact sports, such as football, this mechanism is often sudden and traumatic. However, in dance, it is believed that this mechanism may be operative chronically, that is, that repetitive forced turnout may result in long-term wearing and splitting of the meniscus (Quirk, 1987; Scioscia, Giffin, and Fu, 2001; Silver and Campbell, 1985). Dancers have also reported meniscal injury associated with losing balance or twisting when in a position of deep knee flexion such as that associated with floor work in modern or jazz, or center floor first or fifth grand pliés. In full flexion the menisci are pinched between the articulating bones; and if there is a twist in this vulnerable position, injury can readily occur. To lessen injury risk, full weighted knee flexion should be used cautiously, with appropriate progressions for beginners, and with an emphasis on good form.

In some cases of acute meniscal injury, a "popping" or "tearing" sensation is experienced, followed by severe pain (Mercier, 1995). More frequently, symptoms include moderate pain that gradually subsides (Diduch, Scuderi, and Scott, 1997). It is common to have localized tenderness on the joint line over the meniscus. Swelling is generally slow, often not reaching a maximum until the day after the initial injury, and may recur on multiple occasions (Scioscia, Giffin, and Fu, 2001). Grand pliés may be painful, and range of knee motion may be limited. There is often apprehension about assuming the position of a full squat. In the days or even weeks following the initial injury, painful locking, catching, or giving way, especially with flexion and twisting movements, often occurs. Quadriceps femoris atrophy generally proceeds rapidly.

Initial recommended treatment for meniscal injury often involves limiting activity, ice, compression, elevation, and anti-inflammatory medications, followed by quadriceps strengthening (Diduch, Scuderi, and Scott, 1997; Mercier, 1995). Many small meniscal tears, especially small ones located in the outer third of the meniscus where the blood supply is adequate (figure 5.33B), can heal spontaneously. However, if the knee does not respond adequately to conservative therapy or there are repeating episodes of catching, locking, or giving way, surgery is often recommended. These episodes can relate to encroachment of the torn portion of the meniscus into the joint, where it can be caught between the condyles, as shown in figure 5.33, C and D. If allowed to continue, this mechanical impingement
Extensor Mechanism Injury

Any component of the extensor mechanism—including the quadriceps muscle itself, the tendons of the quadriceps, and the patella—can be injured, but the latter two are particularly commonly involved. A description of several injuries involving these latter two structures follows.

Patellofemoral Pain Syndrome  Patellofemoral pain syndrome refers to anterior knee pain that relates to the patella and associated retinacular support as seen in figure 5.34A. In cases in which there is documented damage to the thick cartilage that lines the backside of the patella, patellofemoral pain can be more specifically classified as chondromalacia patella, which literally means soft (“malacia”) cartilage (“chondro”). Patellofemoral pain is the most prevalent type of knee pain in adolescents and young adults, and one of the most common complaints bringing athletes to sports medicine clinics (Caillet, 1996; Garrick, 1989; Mercier, 1995; Weiker, 1988). Patellofemoral pain is commonly seen in activities involving high-impact or repetitive knee flexion. Since dance contains both of these elements, it is not surprising to find patellofemoral pain syndrome prevalent in the dance population. In a survey of 362 pre-professional and professional modern and ballet dancers, 38% reported having three or more classic symptoms of patellofemoral pain syndrome associated with dance at some time during their dance training (Clippinger-Robertson et al., 1986).

In addition to the high and repetitive compression forces associated with dance, there are other underlying anatomical and biomechanical factors that tend to increase risk for patellofemoral pain. For example, factors that tend to produce decreased stability of the patella such as genu recurvatum and weakness of the vastus medialis—as well as factors that tend to produce patellar malalignment such as genu valgum, excessive femoral anteversion, an increased Q angle, or a tight iliotibial band—can all increase risk for patellofemoral pain syndrome (Grabiner, Koh, and Draganich, 1994; Reider, Marshall, and Warren, 1981; Sheehan and Drace, 1999; Winslow and Yoder, 1995). Some of these latter malalignments are commonly seen grouped together, and the composite is termed the miserable malalignment syndrome as seen in figure 5.34B. In general, patellofemoral pain syndrome occurs more frequently in females than in males. This is believed to be due to the greater Q angle and valgus vector associated with the wider pelvis, the tendency for greater genu recurvatum, or greater quadriceps weakness found in females versus males. In essence, patellar instability

The Terrible Triad

With some injuries, multiple structures can be involved. When a rotational component is added to the medially directed force on the knee, the ACL and medial meniscus, as well as the medial collateral ligament, can be injured simultaneously. This combination injury is termed the “terrible triad” (G. trias, three). It is a serious injury that requires prompt medical diagnosis and treatment.
and malalignment factors are believed to allow abnormal lateral excursion of the patella against the lateral lip of the femoral groove, causing excessive patellar shear stress.

Classic symptoms of patellofemoral pain syndrome include (1) generalized (nonspecific) pain behind or around the patella, and particularly medial to the patella; (2) pain with knee flexion such as in grand pliés; (3) pain with extended sitting; (4) pain going down stairs; and (5) weakness, swelling, and pain during or after activity. One of the symptoms that most clearly distinguishes patellofemoral pain syndrome from other knee injuries is pain with extended sitting, such as in a theater, a car, or a plane. While other injuries often are pain free with rest, the quadriceps are slightly stretched by the bent knee position accompanying sitting, producing a small amount of patellofemoral compression and thus pain. A medical evaluation will classically reveal pain when applying pressure to the backside of the patella, and swelling and crepitus may be present (Mercier, 1995). Relative atrophy of the vastus medialis is also usually apparent, and other malalignment or instability factors previously discussed are commonly present.

Initial recommended treatment often involves ice after activity, modified activity, and anti-inflammatory medication (Garrick, 1989; Roy and Irvin, 1983). Dance movements associated with high compression forces or pain, such as pliés, lunges, jumps, and floor work, should be temporarily avoided or modified to utilize a pain-free range (table 5.6).

However, the most important aspect of successful long-term rehabilitation is the development of quadriceps strength to counter the valgus tendency and restore optimal patellar tracking. Unfortunately, quadriceps atrophy appears to occur rapidly, and reflex inhibition can reduce the ability of the quadriceps to produce desired force within hours (Kennedy, Alexander, and Hayes, 1982; Urbach et al., 1999). Many classic exercises used to strengthen the quadriceps muscles will tend to aggravate the condition. Hence, a closely supervised physical therapy program initially using isometric (e.g., quad set and straight leg raise, table 5.3, A and B) and small arc exercises (terminal knee extension, table 5.3C)
in which compression forces are low, and with careful attention to activating appropriate muscles and avoiding knee hyperextension, is usually very effective. When quadriceps atrophy or apparent inhibition is marked, electrical stimulation of the quadriceps femoris muscle while the dancer superimposes conscious contraction may also be prescribed.

Attention to and correction of any underlying abnormalities or technical errors that can be improved, such as a tight iliotibial band, genu recurvatum, or forced turnout, can also be helpful. In the author’s experience, working with dancers to maintain turnout at the hip and emphasize use of the hip abductors, while de-emphasizing use of the quadriceps during movements such as turned-out pliés, can also often provide symptom relief (Cappinger-Robertson et al., 1986). In some cases, taping techniques (McConnell taping) or a brace (patellar stabilization brace) may have a subtle positive influence on joint mechanics (Jenkinson and Bolin, 2001; Powers et al., 1999) while adequate quadriceps strength is being developed.

Although in a vast majority of cases conservative treatment emphasizing quadriceps strengthening will be successful in relieving symptoms, in a small number of nonresponsive cases, surgery may be recommended (Weiker, 1988). One common surgical approach is to resurface the posterior side of the patella and try to encourage cartilage healing. Another surgical approach utilizes various procedures to improve the alignment of the extensor mechanism.

**Jumper’s Knee**  Jumper’s knee refers to injury to the patellar tendon right at its junction with the inferior pole of the patella as seen in figure 5.35. Some authors have also included injury to the quadriceps tendon at its junction with the superior patella within this terminology (Bergfeld, 1982; Blazina et al., 1973; Cook et al., 2000). Jumper’s knee is believed to involve an initial acute tear of the quadriceps tendon during a movement involving an explosive contraction of the quadriceps muscle. Then, before this site has time to heal, additional trauma aggravates the injury and it becomes chronic, often with a small area of granulation tissue at the site of the original tear (Quirk, 1987).

As its name implies, this injury is particularly common in athletes participating in sports involving jumping, such as volleyball or basketball players. It can also be found in sports that repetitively stress the quadriceps such as running, kicking, or climbing. Considering that dance contains both jumping and many repetitive movements that stress the quadriceps, it is not surprising that jumper’s knee occurs readily in dancers. Factors that have been theorized to further increase the risk for this injury in dancers include participation in very athletic roles involving a lot of jumping (Quirk, 1987), excessive increase in dance workload, abrupt change in dance style, performing on hard floors, inadequate quadriceps strength, growth spurts, and calf tightness leading to a limited plié that requires large forces to be absorbed in a short period of time (Khan et al., 1995; Poggini, Losasso, and Iannone, 1999; Quirk, 1987).

**FIGURE 5.35** Jumper’s knee and associated site(s) of pain (right knee, lateral view).
Pain is classically of insidious onset and is centered in the tendon just superior or just inferior to the patella (Blazina et al., 1973). This pain is generally "aching" in nature and usually goes away after a period of rest. In milder forms of tendinitis, the pain will often appear at the beginning of activity, disappear or decrease significantly after "warming up," and then reappear after completion of activity. In more advanced stages, the pain becomes more persistent and will tend to be present before, during, and after activity. In general, this pain is aggravated by performing jumps and can be reproduced by extending the knee against resistance. In some cases, the pain is accompanied by a sensation of "weakness" or "giving way."

Commonly recommended treatment for milder forms of jumper's knee involves heat or extra warm-up prior to activity (or both), ice after activity, anti-inflammatory medication, and in some cases physical therapy modalities (Bergfeld, 1982). Jumping and other high-load flexed movements of the knee are temporarily avoided as quadriceps strengthening and stretching are initiated (Diduch, Scuderi, and Scott, 1997). Although quadriceps strengthening is essential, full arc or plyometric types of exercises often aggravate the condition and should be avoided. Instead, initial treatment often involves terminal knee extension exercises (table 5.3C, p. 275) performed in a pain-free range of motion, as well as straight leg raises (table 5.3B, p. 275) with the knee in a position that is pain free (often requiring a very slightly flexed vs. fully extended position). Later stages of therapy may include eccentric quadriceps strengthening. In addition, technique factors such as poor landing mechanics with jumping should be corrected if indicated. In most cases, conservative treatment will lead to successful rehabilitation. However, if it should fail, some physicians recommend that the small area of granulation tissue within the quadriceps tendon be surgically excised (Quirk, 1983, 1987).

**Osgood-Schlatter Disease**

Osgood-Schlatter disease also involves the quadriceps tendon; but in contrast to jumper's knee, it involves the inferior attachment of the patellar tendon where it joins to the tibial tuberosity as seen in figure 5.36. This condition is not really a disease but rather involves an injury to the growth center of the tibial tuberosity (apophysis) due to traction produced by the quadriceps via the patellar tendon (Micheli, 1987). This injury usually becomes evident between 8 and 15 years of age, and especially during the peak of the adolescent growth spurt (Mercier, 1995; Stanitski, 1993). Although in the general population it is more prevalent in males than females, in adolescent dancers it is common in both genders. Osgood-Schlatter disease is common in athletics involving rigorous or repetitive quadriceps contraction such as with running, jumping, and grand pliés. Factors discussed in the context of patellofemoral pain syndrome that tend to produce patellar malalignment will also increase the stress to the quadriceps tendon and may increase the risk for Osgood-Schlatter disease as well.

Osgood-Schlatter disease is characterized by pain and swelling over the tibial tuberosity. The tibial tuberosity is generally exquisitely tender to the touch or when pressure is applied, such as with kneeling, and it sometimes becomes enlarged.

Recommended treatment often includes ice after activity and anti-inflammatory medications (Stanitski, 1993). Dance should be modified to reduce movements that produce tendon stress and pain such as the grand plié, deep fondu, and jump. Knee pads with a felt or foam horseshoe fashioned to take the direct pressure off the tibial tuberosity can be worn if dance choreography requires floor work, and braces are sometimes prescribed (Micheli, 1987). Quadriceps strengthening, quadriceps stretching, and correction of any related technique factors can also sometimes provide relief. Luckily, this condition is almost always self-limiting and goes away when the tuberosity unites with the main part of the tibia (Diduch, Scuderi, and Scott, 1997; Quirk, 1987). However, if pain persists into adulthood, it is impor-
tant for the person to get rechecked by a physician, as in some cases a fragment of the tibial tuberosity may actually fully detach.

**Rehabilitation of Knee Injuries**

Although treatment approaches will vary in accordance with the type of injury and other factors, one common rehabilitation concern is effective restoration of quadriceps strength and function. The quadriceps femoris muscles, and particularly the vastus medialis, appear to be quite prone to muscle inhibition following surgery, injury, or even relatively minor trauma or swelling (Hopkins et al., 2001). **Muscle inhibition** is the inability to fully activate the motor units in a given muscle with a voluntary contraction. This inhibition tends to produce muscle weakness, atrophy, and decreased neuromuscular control. Researchers have found 20% deficits in quadriceps strength to be common, with more severe deficits ranging from 30% to 45% occurring in some instances (Hurley, Jones, and Newham, 1994; Suter and Herzog, 2000).

The inhibition and related strength deficits can also be very persistent, evident months and even years after the original injury. For example, an average of 20% knee extensor inhibition was found in patients 22 months after ACL reconstructive surgery. Such decreases in quadriceps strength potentially interfere with restoration of normal knee function, increase the risk of reinjury, and may predispose the knee joint to degenerative diseases such as osteoarthritis. This extensor inhibition has been shown to occur commonly with both acute and chronic injuries and may involve the uninjured as well as the injured limb, making it advisable to use the uninjured side as “normal” when one is performing strength tests (Urbach et al., 1999). Hence, effective rehabilitation is recommended for even relatively minor knee injuries so that more serious or recurrent knee injuries can be avoided.

**Summary**

The knee joint proper is formed between the respective medial and lateral condyles of the femur and tibia and is called the tibiofemoral joint. The tibiofemoral joint is a modified hinge joint that primarily allows flexion and extension, but also some transverse rotation. Although the articular contact area is very broad, the shallowness of the joint makes it inherently unstable. Additional necessary stability is provided through a combination of ligaments, the joint capsule, the menisci, and strong muscles.

The cruciate ligaments are key stabilizers to limit anterior-posterior movement and rotation, as well as guiding the sliding of the femur relative to the tibia during knee flexion. The collateral ligaments are key stabilizers in the frontal plane to limit medial-lateral movement and valgus-varus stress. The iliotibial band provides additional lateral support to the knee. Overlying the ligaments and capsule are 12 muscles and their tendons, which provide additional support as well as movement. The action of the quadriceps femoris is knee extension, while the hamstrings and remaining muscles produce knee flexion, slight rotation, or both. In a weight-bearing position, once the knee begins to flex, gravity will tend to make it flex further. Hence, the knee extensors play a critical role not only to produce concentric knee extension, but also to isometrically maintain a bent position of the knee or eccentrically control additional flexion of the knee.

Tibiofemoral design favors both stability and mobility, partly achieved through static structural elements, such as the broadness of the joint (favoring stability) and the shallowness (favoring mobility). These contrasting demands are also met through the tibiofemoral joint's ability to change its characteristics with position. When the knee is straight, broad articular surfaces provide support, major ligaments are taut, rotation is limited, and stability is favored. However, when the knee bends, the collateral ligaments become slack, forces that would tend to dislocate the joint increase, rotation increases, and mobility is favored. This mobility is desirable to allow pivoting-type movements when the foot is weight bearing and positioning of the foot in space when the foot is free. However, this increased instability also can leave the joint at greater risk for injury. Common alignment deviations such as genu varum, genu valgum, and genu recurvatum can also influence injury predisposition. To foster optimal knee mechanics and prevent injury it is important that dancers develop adequate and balanced strength and flexibility in the key musculature; emphasize optimal mechanics; and avoid positions or movements that produce excessive valgus, varus, or rotation of the knee.

The patellofemoral joint is formed between the posterior surface of the patella and the underlying femoral groove. In contrast to what occurs with the tibiofemoral joint, the stability of the patella is low when the knee is in a position of extension but increases as flexion of the knee proceeds. However, because it is a sesamoid bone and there is not a true "joint" between the patella and the underlying femur, stability and excursion of the patella are markedly