

Physical Exam for Athletic Knee Injuries in Pediatric Patients

Jennifer J. Beck, MD¹; Emily L. Niu, MD²; Aristides I. Cruz Jr.³, MD, MBA; Andrew Pennock, MD⁴; Zachary Stinson, MD⁵; Allison E. Crepeau, MD⁶; Curtis VandenBerg, MD⁷; Kevin G. Shea, MD⁸; Pamela J. Lang, MD⁹; Henry Bone Ellis Jr., MD¹⁰

¹Orthopaedic Institute for Children/UCLA, Los Angeles, CA; ²Children's National Medical Center, Washington, DC; ³Hasboro Children's Hospital, Providence RI; ⁴Rady Children's Hospital, UCSD, San Diego, CA; ⁵Nemours Children's Hospital, Jacksonville, FL; ⁶Connecticut Children's, UConn, Hartford, CT; ⁷Childrens Hospital Los Angeles, Los Angeles, CA; ⁸Stanford University, Stanford, CA; ⁹American Family Children's Hospital, University of Wisconsin, Madison, WI; ¹⁰Texas Scottish Rite, Dallas, TX

Abstract:

The clinical examination of the child or adolescent with a knee injury or pain can vary based on the age of the patient as well as the acuity of the problem. When pediatric patients present with thigh or vague knee pain, the importance of the hip examination cannot be overemphasized. Evaluating the uninjured extremity first is particularly valuable to building trust and confidence with a scared, nervous patient. Having the patient describe and point to locations of symptoms can assist in prioritizing physical exam maneuvers, as creating pain early in the exam will limit later exam compliance. Similarly, allowing patient to first demonstrate active range of motion prior to passive range of motion and provocative testing can minimize apprehension and pain for the patient. There are four primary elements of the exam: observation, palpation, static stability examination, and dynamic assessment. This review article will summarize physical exam techniques and pertinent findings for meniscal, ligamentous, and patellofemoral pathology.

Key Concepts:

- Gait evaluation should be performed on any patient capable of walking.
- Inspection and palpation for effusion is critical for determining presence of intraarticular pathology.
- Focused physical exam based on differential diagnoses should be performed on the uninjured, contralateral side to gain patient trust and compliance.
- Any pediatric patient presenting with vague knee or medial thigh pain should be evaluated for hip pathology.

Introduction

The clinical examination of the child or adolescent with an athletic knee injury or pain can vary based on the age of the patient as well as the acuity of the problem. After reading this paper, please watch the accompanying POSNA-Sports QSVI video on Evaluation of the Pediatric Knee. There are four primary

elements of the knee exam: inspection, palpation, static stability examination, and dynamic assessment including an evaluation of the child's gait, balance, and jump mechanics. An important consideration in this younger population is establishing trust with the patient. This can be achieved by explaining the examination to the child prior

to proceeding. Additionally, evaluating the uninjured extremity first is particularly valuable in this respect. Also, enabling the patient to first voluntarily demonstrate areas of pain and also active range of motion prior to palpation and provocative maneuvers enhances this trust. Building confidence with the parent is also important because they are often just as anxious as the patient.

When pediatric patients present with thigh or vague knee pain, the importance of the hip examination cannot be over-emphasized. Patients with underlying Slipped Capital Femoral Epiphysis (SCFE) or Legg-Calve-Perthes (LCP) will often present with referred thigh or knee pain (due to the sensory distribution of the obturator nerve), and hip pathology can often be identified if hip motion reproduces the pain or any asymmetry of hip motion is noted such as loss of internal rotation (Figure 1) or obligate external rotation (please watch the accompanying SCFE Exam video).



Figure 1. Perthes Disease of the right hip presenting with asymmetric loss of internal rotation on prone hip examination.

Furthermore, excessive femoral anteversion and gluteal weakness have been associated with multiple knee pathologies, including ligament tears, patellofemoral instability, and anterior knee pain. These conditions can be identified easily on examination by documenting increased hip internal rotation (> 45 degrees), most easily seen on prone examination of hip rotation (Figure 2), and testing gluteal strength with a standing Trendelenburg examination, respectively. The rotational profile of the lower extremities can be further characterized by



Figure 2. Excessive femoral anteversion as diagnosed by increased, symmetric internal rotation.



Figure 3. External tibial torsion diagnosed by thigh-foot axis greater than 15 degrees.

measuring tibial rotation using the thigh-foot axis (normal is neutral to 15 degrees externally rotated; Figure 3) and inspecting the foot and ankle for evidence of pes planovalgus.

General Physical Exam

Visual Inspection

Appropriate attire (gym shorts or examination shorts) is essential for a thorough examination. An important visual finding is the presence of an intraarticular knee effusion, which almost certainly denotes significant underlying pathology and prompts the ordering of advanced imaging or laboratory values (Figure 4).

Effusion typically lies in the suprapatellar pouch, so using the ballotment test (please watch the Ballotable Patella video) by starting proximal to the suprapatellar pouch and directing force distally to move trapped fluid behind the patella will result in an outpouching of fluid along the sides of the patella. This may be observed visually, but it is also easily palpated. Focal, superficial swelling (prepatellar, tibial tubercle, pes anserine, joint line, etc.) and bruising should also be documented because it may guide the clinician towards a more specific diagnosis.

Figure 4. Visually seen and palpable right knee effusion can be confirmed with ballotment of the patella (see accompanying video).



Palpation

Focused palpation should evaluate the relevant anatomy related to the pathology that is in the differential diagnosis. Palpating the most painful location should be performed last to avoid guarding and increase patient compliance with the exam. Consideration to potential osseous or soft tissue injuries should prompt specific, focal palpation, keeping in mind underlying anatomy. Specific to pediatric acute knee injuries, palpation of growth plates should be completed to rule out injuries or determine the need for radiographs.

Range of Motion

Evaluating knee range of motion includes identifying asymmetry in motion, pain with either terminal flexion or extension, mechanical symptoms that occur with motion, or excessive hyperextension of the knee (recurvatum > 10 degrees). Hyperextension is common in the pediatric population, where generalized laxity is frequently observed and can be a risk factor for injury. If there is a

concern for an underlying collagen disorder, this can be more formally assessed with the Beighton Score (Table 1).¹ Prone evaluation with feet hanging off the edge of the bed and assessment of heel height difference may improve sensitivity to detecting subtle extension loss (Figure 5).



Figure 5. Evaluation of heel height in prone position (A) with feet hanging off the bed can reveal subtle extension loss more difficult to assess on supine examination (B).

Gait Examination

In ambulatory patients, a weight bearing examination is helpful to not only assess the limb alignment and any leg length difference, but also to assess any gait abnormalities. Documenting the foot progression angle can be particularly helpful in patients with rotational abnormalities of the extremity indicating hip pathology, femoral version, or tibial torsions. In patients with significant quad-

Table 1. The 9-Point Beighton Score of Hypermobility

Description	Bilateral Testing	Scoring (max. points)
Passive dorsiflexion of the fifth metacarpophalangeal joint to ≥ 90 degrees	Yes	2
Passive hyperextension of the elbow ≥ 10 degrees	Yes	2
Passive hyperextension of the knee ≥ 10 degrees	Yes	2
Passive apposition of the thumb to the flexor side of the forearm, while shoulder is flexed 90 degrees, elbow is extended, and hand is pronated	Yes	2
Forward flexion of the trunk, with the knees straight, so that the hand palms rest easily on the floor	No	1
Total		9

riceps weakness, external foot progression angle may also be present as a compensatory mechanism on the affected extremity. Having the patient perform a single leg or deep squat may narrow the differential diagnosis or expose subtle muscular or balance asymmetries. More dynamic assessment including a step-down test or vertical jump test can be helpful in assessing core musculature deficiencies and functional deficits. While muscular dystrophies are relatively rare, they often present initially to pediatric orthopaedic providers. If any deficiencies in core strength are identified, the patient should also be assessed for the presence of a Gower sign.

Meniscus Exam

The central two thirds of the meniscus is avascular and does not have innervation, resulting in some meniscus tears not causing swelling or pain. The provocative tests described below should be combined for the highest diagnostic accuracy.²

Inspection and Range of Motion

On standing exam, evaluation of alignment abnormalities, inability to straighten the knee, or visible effusion should be completed. In an acute meniscus tear, an antalgic gait may be seen. The patient should then be examined in the supine position and assessed for a visible or palpable effusion and motion deficits compared to the contralateral side. Prior to attempting range of motion, the clinician should place a finger over the concerned joint line to palpate for clunks or mechanical symptoms while taking the knee through motion. Pain with provocative flexion that is localized posteriorly may suggest a posterior horn meniscus tear. Inability to achieve terminal extension or flexion may indicate a displaced meniscus tear. Popping or pain along the joint line may indicate pathology such as a discoid lateral Meniscus. Please watch the accompanying Discoid Meniscus video.

Palpation of Joint Line Tenderness

Palpation along the medial and lateral joint line for tenderness is a simple exam, yet it is also the most sensitive

of the meniscal testing maneuvers. The knee is brought into maximum flexion which brings the anterior horns of the menisci into greater prominence. Palpation along the anterior joint line medially and laterally can then be performed while asking the patient whether they feel discomfort. Maintaining the knee flexion and internally rotating the tibia presents the body of the medial meniscus which can then be palpated for tenderness. Conversely, the tibia is externally rotated to palpate along the body of the lateral meniscus. The knee can also be brought into a figure-of-four position to open the lateral joint line during palpation. This allows for differentiation of tenderness along the body of the meniscus versus overlying structures such as the lateral collateral ligament and iliotibial band. Finally, the posterior horns are deep structures that are difficult to palpate and therefore pain with provocative flexion may be better for assessing this area of the meniscus.

A prospective study of 161 knees where meniscal tears were confirmed arthroscopically found that tenderness along the joint line had a sensitivity of 85% and specificity of 29.4%.³ Another prospective, blinded study of 160 patients with arthroscopically confirmed meniscus tears found that joint line tenderness testing had sensitivity of 55% and specificity of 67%.⁴

McMurray Test

First described by McMurray in 1942,⁵ this test is a circumduction test intended to detect tears of the posterior horn of the meniscus. The test is performed with the patient lying supine. Grasping the patient's foot, the knee is brought into maximum flexion while the thigh is held stable by the other hand. Maintaining the position of flexion, the lower leg is rotated externally to engage the posterior horn of the medial meniscus under the medial femoral condyle and internally to engage the posterior horn of the lateral meniscus under the lateral femoral condyle. External rotation is maintained while the knee is brought from flexion to extension. This is repeated with the leg internally rotated and the knee brought from flexion to extension. As originally described, the test is positive if the patient experiences an audible or palpable

click or pop with associated pain as the knee is brought from flexion into extension. Modifications allow for positive joint line pain along the meniscus being tested to also be considered a positive finding.

A positive medial McMurray test had sensitivity of 50% and specificity of 77% for medial meniscus tear while positive lateral McMurray test had sensitivity of 21% and specificity of 94% in 109 patients presenting with history suspicious for meniscus tear with confirmation by MRI and arthroscopy.⁶ When combined with positive joint line tenderness, the accuracy increased to sensitivity and specificity of 91% for medial meniscus tear and sensitivity of 75% and specificity of 99% for lateral meniscus tear.

Apley Compression Test

Described in 1947 by Apley⁷ as an alternative to the McMurray test, this test is performed with the patient lying prone. The table should be low enough that the examiner is able to place their knee over the patient's thigh in order to stabilize the femur. The knee is then flexed to 90 degrees and the examiner holds the foot in order to rotate the lower leg. External rotation is applied forcefully to test the medial meniscus. The rotation is performed with neutral load across the knee, followed by distraction, and then compression. As originally described, pain with rotation while applying a distraction force implies a "rotational sprain," while pain while applying compression and rotation indicates a meniscus tear. The process is repeated with internal rotation to test the lateral meniscus, and the knee can be maximally flexed while performing the test to assess the posterior horn. However, due to the lack of examination tables low enough to apply an adequate distraction force, modifications have been made to only perform the compression portion of the test with external or internal rotation of the knee.

A systematic review of 18 studies reported on the sensitivity and specificity of physical exam maneuvers for meniscus tears.⁸ For the Apley test, the pooled sensitivity was 60.7% and specificity was 70.2% with wide heterogeneity among studies ranging from 13% to 70% for sensitivity and 33% to 100% for specificity. These findings

were comparable to the pooled results for McMurray and joint line tenderness testing.

Thessaly Test

First described by Karachalios et al. in 2005,⁹ the Thessaly test is performed with the patient standing on one foot with the knee flexed to 20 degrees, first on the normal side and then on the symptomatic side. The examiner or a companion to the patient can lend support while the patient maintains the knee flexion and rotates their body internally and externally which creates a dynamic load stress across the meniscus. A positive result is recorded with joint line pain or popping. A specific benefit of this test is the ability to perform it via telemedicine evaluations since it can be performed by the patient independently without the need of an experienced clinician performing the maneuver.

When comparing meniscus physical exam techniques, Karachalios et al. found that the Thessaly test at 20 degrees of knee flexion compared favorably to other tests for meniscal tears with high sensitivity of 89% for medial meniscus tear and 90% for lateral meniscus tears as well as high specificity of 97% for medial meniscus tears and 96% for lateral meniscus tears.⁹ However, Konan et al. found that diagnostic accuracy of the Thessaly test was comparable to that of the McMurray test, with medial meniscus sensitivity and specificity of 59% and 67%, respectively, and lateral meniscus sensitivity and specificity of 31% and 95%, respectively.⁶

Anterior Cruciate Ligament (ACL)

Patients may present in an acute, subacute, or chronic phase after ACL tear and will have different physical examinations at each phase. If concern for multi-ligament knee injury is high, a meticulous distal neurovascular exam, including possible Ankle-Brachial Index (ABI), should be completed. Please watch the accompanying ACL Exam video.

Inspection and Range of Motion

Inspection for intraarticular effusion presence or resolution will help determine the chronicity of an ACL injury:

large effusions from acute tears, resolution in a subacute phase, followed by small, recurrent intraarticular effusions in chronic tears. Range of motion is critically important to evaluate for possible displaced meniscus tears that may occur with ACL tears.

Palpation

In an acutely injured knee, focused attention to palpation around the distal and femoral physes and extensor mechanism will help rule out more severe injuries. Specific palpation at the femoral, tibial, and fibular collateral ligament attachments as well as medial and lateral joint lines will help determine coexisting pathologies. Tenderness around Gerdy's tubercle (lateral, proximal tibia) could be indicative of an anterolateral ligament injury or Segond fracture that can accompany ACL tears. Subacute and chronic injury exam focus is on adequacy of collateral ligament healing and laxity and joint lines as residual sources of pain and pathology.

Lachman Test

The Lachman test is the classic examination for diagnosing ACL tears via anterior translation of the tibia on the femur.¹⁰ Especially in hypermobile teenage females and patients < 12 years of age, assessing the uninjured side will provide a baseline examination for which to compare the injured knee. When performed, the knee should be flexed to 30 degrees and the patient relaxed and reassured to avoid muscle guarding. While standing towards the distal aspect of the patient's knee, one hand firmly holds the distal femur in a stable position. The second hand is placed around the proximal tibia and with a gentle anterior translational force, attempts to move the tibia anteriorly relative to the distal femoral condyles. Ensuring the femoral hand is holding steady, the examiner determines if increased anterior translation of the tibia is present. Patient relaxation and cooperation are paramount for getting an accurate exam. Grading systems have been described; however, assessing for asymmetry is of main importance. In addition, side-to-side differences can be compared for the presence or absence of a firm endpoint. If there is difficulty with body habitus, placing the patient's foot off the

side of the bed and pinning it to the table with your hip may assist in the exam.

Anterior Drawer Test

The anterior drawer test is a commonly reported physical exam maneuver assessing anterior translation of the knee in ACL injuries. It can be misleading if done improperly which accounts for its limited utility. When performing a proper anterior drawer test, it is critical to assess the starting position of the tibia relative to the distal femur. The knee is flexed to 90 degrees. Placing the thumb tip on each medial and lateral distal femoral condyles and the corresponding thenar eminence on the proximal tibia will aide in determining if the tibia is sitting posterior to the femoral condyles (indicating a PCL tear) or inline with the femoral condyles. If the tibia and femoral condyles are inline, then gentle anterior translation of the tibia on the distal femur can show increased translation in the setting of an ACL tear. Comparing this to the unaffected side can be helpful. This exam can be particularly useful if you have difficulty controlling the leg at 30 degrees for a Lachman exam due to patient size or body habitus.

Lever Sign

The Lever sign is a more recently described test of ACL injuries.^{11,12} The patient lies in a supine position with the injured knee in full extension and the heel resting on the examination table. A closed fist is placed under the proximal third of the calf at the level of the tibial tubercle while the examiner's other hand pushes in an anterior-to-posterior direction on the distal third of the quadriceps muscle. A negative test (intact ACL) will result in the heel rising off the table. With a positive test (ACL tear), the heel will remain on the table as the tibia slides anteriorly on the femur (positive result).

Pivot Shift

The pivot shift test evaluates the rotatory instability of the knee with limited clinical reliability unless performed on chronic ACL injuries or anesthetized patients, as this is not well tolerated in a typical clinic setting.¹³

During the pivot shift maneuver, the examiner is attempting to rotate and sublunate the lateral tibial plateau with respect to the lateral femoral condyle by using internal rotation and valgus stress with the knee in full extension. When the exam is positive, the iliotibial band assists in “reducing” the anterolateral subluxation of the lateral tibial plateau as the knee is brought into 25–30 degrees of flexion.

Other Ligament Injuries

Posterior Cruciate Ligament (PCL)

Inspection

PCL injuries are rarer than ACL injuries but should be considered in any acute knee injury. Inspection can be a powerful tool for this injury. Please watch the accompanying PCL Exam video. The Posterior Sag sign is an easy maneuver completed by flexing both knees to 90 degrees on the examination table. The injured proximal tibia will sit posterior to the uninjured side and posterior relative to the femoral condyles. After a positive finding, the Quad Activation test can be completed by asking the patient, with knee flexed to 90 degrees and the foot held fixed to the table, to attempt to straighten their knee. This should show anterior translation of the tibia and reduction to a normal position under the femoral condyles. Relaxation of the quadriceps will show return of the posteriorly displaced tibia on the femoral condyles.

Posterior Drawer

Another dynamic test for PCL insufficiency is the Posterior Drawer test. While the knee is flexed to 90 degrees and the foot fixed to the table, the examiner must confirm first the location of the tibial plateau in comparison to the femoral condyles. Using thenar eminences on the tibia and thumb pads on the femoral condyles, this relationship can be established. If the thenar eminences are posterior to the thumb pads, the tibia is subluxated posteriorly, and prior to an attempt at a posterior drawer maneuver, the tibia should be reduced inline with the femoral condyles. Subsequently, a posteriorly directed

translational force is applied to determine PCL insufficiency relative to the contralateral knee.

Collateral Ligaments

Palpation

In skeletally immature patients, varus and valgus injuries should give rise to concern for physeal injuries that may happen more readily than collateral ligament injuries. Palpation around the distal femoral and proximal tibial physis should be completed. Physeal tenderness should prompt radiographic examination.

Varus and Valgus Stress Testing

Medial Collateral Ligament (MCL) injuries should be evaluated in both 0 and 30 degrees of knee flexion. The MCL is more specifically isolated at 30 degrees of flexion while valgus instability with the knee in terminal extension indicates concurrent ACL insufficiency in addition to MCL injury. Application of external rotation during valgus stress testing may increase sensitivity of the testing. Varus testing can be performed with a free foot or in a figure-of-4 position. When a posteriolateral corner (PLC) injury is suspected, the Dial Test should also be completed: external rotation of the tibia will show an increased side-to-side difference of > 10 degrees when the knee is flexed at 30 degrees for an isolated PLC injury and at 90 degrees if both the PCL and PLC are disrupted.

Patellofemoral Pathology and Extensor Mechanism Injuries

Anterior knee pain and injuries are a common complaint among pediatric and adolescent patients. Quadriceps (Prone knee flexion), hamstring (Popliteal angles), and Iliotibial Band (Ober test) should be performed in chronic knee pain complaints to determine tightness within these tissue groups. Patella instability can present in a similar fashion to ACL tears, so physical exam should include consideration of both pathologies in the acutely swollen knee. A straight leg raise is a critically important part of the physical exam to assess for an intact extensor mechanism. However, patient guarding and anxiety may limit the utility of this test and a high

index of suspicion should be utilized with careful palpation of the patellar and quadriceps tendons and observation of the position of the patella compared to the contralateral side.

Extensor Mechanism Injuries

Pediatric and adolescent patients may present with either acute or overuse injuries to the extensor mechanism of the knee (the quadriceps tendon, the patella, and the patellar tendon). Acute injuries to the extensor mechanism in this age group are often patellar sleeve fractures or tibial tubercle fractures. Overuse injuries resulting in anterior knee pain can include patellofemoral pain syndrome, painful medial plica, Osgood Schlatter's Disease, patella tendonitis, and Sinding-Larsen-Johanssen. Clinical history including duration and nature of onset of symptoms can help distinguish between an acute or overuse injury. Combining information gathered from the history and physical examination is critically important in differentiating these pathologies.

Palpation

Palpation of the patellofemoral joint should be specific and focused for conditions in the differential diagnosis. This should include the medial and lateral patella facets (patella chondromalacia, patella osteochondritis dissecans [OCD] or patellofemoral syndrome), medial and lateral femoral trochlea (trochlear OCD or patella dislocation), inferior pole of the patella (Sinding-Larsen-Johansen vs. patella sleeve fracture), the patellar tendon (patella tendonitis), the tibial tubercle (Osgood-Schlatters vs. tibial tubercle fracture), the infrapatellar fat pad (Hoffa's), and the medial plica. In older adolescents with Osgood-Schlatters, fragmentation or ossicles within the tibial tubercle may cause a palpable bony prominence at this site.

Quadriceps Angle (Q-Angle)

The quadriceps angle (Q-angle) is the angle formed between a line extending from the anterior superior iliac spine (ASIS) through the center of the patella and a line extending from the center of the patella through the tibial tuberosity. Increased Q-angles result in a laterally directed force vector during activation of the knee extensor

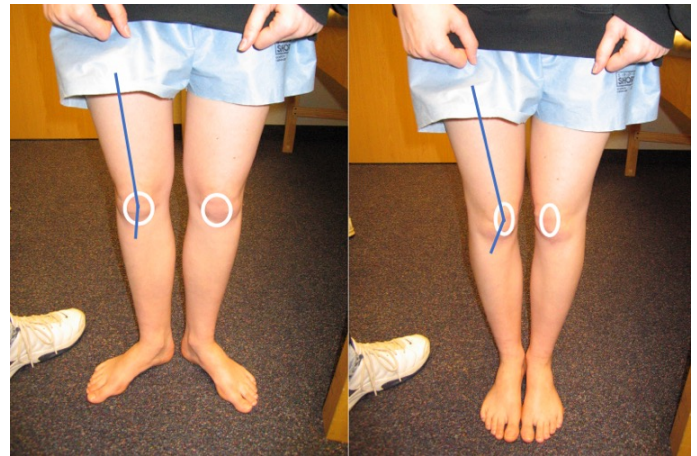


Figure 6. “Miserable malalignment” is diagnosed by excessive femoral anteversion with increased external tibial torsion. (A) With patellas pointing forward, the tibial external rotation is noted by the external foot progression. (B) With a neutral foot progression, “kissing patellas” seen by internally rotated patella position indicates increased femoral anteversion and an a dynamically increased Q-angle.

mechanism causing asymmetric loading of the patellofemoral joint or lateral patellar instability. When evaluating the Q-angle, it is important to note that in addition to the static coronal plane alignment evaluated on supine or standing exam, a dynamic Q-angle assessment is equally as important. This can be done by having the patient perform a double- or single-leg squat or a standard drop-jump test.¹⁴ Finally, it is important to note that rotational malalignment can also contribute to increases in Q-angle. For example, increased femoral anteversion or excessive external tibial torsion can increase the “relative Q-angle” resulting in an excess lateral patellar force vector and contributing to patellofemoral maltracking. Thus, the rotational profile of the hip and tibia are important to note when evaluating a patient for patellofemoral pathology (Figure 6).

Patellofemoral Tracking/Instability

The patella normally engages the trochlea at approximately 30–40 degrees of knee flexion. The patella relies almost exclusively on soft-tissue constraints in full extension, and it is in this position that the patella will be the most susceptible to subluxation/dislocation. It is within this context that the findings following certain physical examination maneuvers become apparent.

J-Sign

In a patient with lateral patellofemoral instability, the “J-sign” can be observed when delayed engagement of the patella into the trochlea during knee flexion results in an abrupt shift of the patella from a lateral to a medial position. Please watch the accompanying J sign video. Conversely, as the knee is extended, the patella is observed to shift from a medial position (while it is engaged within the trochlea) to a lateral position (which may represent lateral patellofemoral subluxation or dislocation).

Patellar Translation Test

This test is performed by manually translating the patella with the knee in 0–20 degrees of flexion. With the patient lying supine and the quadriceps relaxed, the examiner places a laterally directed force on the medial aspect of the patella. The amount of lateral patellar translation is then quantified as the number of patellar quadrants of motion (e.g., < 25% translation = 1 quadrant; 25-50% translation = 2 quadrants, etc.). The test is then repeated in the opposite direction to assess the amount of medial translation.

Patellar Apprehension Test

This test is performed while performing the patellar translation test noted above. A positive test is noted when the patient either verbalizes an impending feeling of patellofemoral instability or if the patient visibly appears apprehensive or uncomfortable during the testing maneuver. The patient may ask the examiner to stop performing the maneuver or may flex the knee or activate their quadriceps in order to prevent patellar subluxation/dislocation. It is important to distinguish a true feeling of apprehension from pain since the latter is less specific for patellofemoral instability than the former.

Summary

The evaluation of pediatric knee pain or injury requires a focused but thorough physical examination guided by the clinical context obtained during the parent and patient history in order to determine an appropriate differential diagnosis and the need for advanced imaging.

Examination of the contralateral, uninjured side will help determine baseline for key maneuvers as well as increase patient and parent comfort. Performing potentially painful or difficult maneuvers at the end of the exam will improve patient compliance.

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