James M. Anderson Center for Health Systems Excellence

Evidence-Based Care Guideline

Conservative Management of Lateral Patellar Dislocations and Instability

In children and young adults aged 8-25 years[a]

Publication date: March 18, 2014

Target Population

Inclusions: Children or young adults:

- With history of lateral patellar dislocation, subluxation or general patellar instability in one or both knees who are going to be conservatively managed
- Ages 8-25 years

Exclusions: Children or young adults:

- Following surgical patellar stabilization techniques
- With Neuro-developmental conditions associated with patellar instability or dislocation (e.g. cerebral palsy, Down Syndrome)

Target Users

Include but are not limited to:

- Athletic Trainers
- Nurse Practitioners
- Other healthcare professionals
- Physical Therapists
- Physicians and physician assistants
- Patients, families, and coaches

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Introduction

References in parentheses ( ) Evidence level in [ ] (See last page for definitions)

Lateral patellar dislocations/subluxations and lateral patellar instability are conditions that can result in short-term and long-term anterior knee pain, functional disability and potentially degenerative joint changes *(Smith 2010b [1b], Fithian 2004 [2a], Atkin 2000 [3b])*. Both conditions are often managed with a non-surgical, conservative approach that entails physical therapy care *(Stefancin 2007 [1b])*. While a variety of expert opinion and review articles have been published with suggestions for physical therapy interventions for lateral patellar dislocation and patellar instability, higher level studies specifically investigating rehabilitation interventions for these conditions are limited. Consequently, optimal physical therapy strategies have not yet been determined *(Smith 2010b [1b])*. Therefore, the purpose of this guideline is to provide a comprehensive description of evaluation and intervention strategies for conservative management of lateral patellar instability.

This guideline was developed based on a synthesis of current evidence relative to the non- surgical, conservative management and treatment of lateral patellar dislocations and patellar instability in children, adolescents, and young adults. Each article from the literature search was individually appraised through a formalized process (described in detail on pages 27-28). Where evidence was insufficient or limited, statements were formulated through a consensus process from a panel of physical therapists. The consensus-based statements regarding progression of injured patients through the identified treatment phases are based on an understanding of current evidence and a consideration of the active, passive, and static stabilizers of the patellofemoral joint, the biomechanical principles relative to joint kinematics and kinetics, and the expected healing properties of the surrounding tissues.

For the purposes of this guideline, "primary patellar dislocation" (PPD) will be used to refer to an acute lateral patellar dislocation or subluxation injury that occurs without prior history of dislocation or subluxation in the involved knee. "Recurrent patellar instability" (RPI) will be used to refer to multiple episodes of lateral patellar subluxation or dislocation that are either insidious in onset or subsequent to a previous primary traumatic dislocation episode. In general, there is much overlap between PPD and RPI with regard to incidence, mechanisms of injury, prognosis, treatment and outcomes. However, for clarity purposes, it can be helpful to discuss PPD and RPI separately in some cases. Therefore, distinct aspects and recommendations for each condition will be discussed separately throughout the guidelines when appropriate.

Objectives of this guideline include:

- To guide and promote consistency in the delivery of optimal evidence-based physical therapy services for non-surgical, conservative management of PPD and RPI
- To promote long-term joint integrity and maximize healing
- To reduce impairment
- To enhance function
- To maintain and improve patient and family satisfaction and quality of life
- To minimize risk for re-injury

Benefits and Expected Outcomes for the patient after following this guideline:

- Full range of motion (ROM) both active and passive in the involved knee
- Ability to participate with self-report of pain less than or equal to 2 out of 10 on Numeric Rating Scale with activities of daily living *(von Baeyer 2009 [4b], Williamson 2005 [5a])*
- Ability to participate with self-report of pain less than or equal to 2 out of 10 on Numeric Rating Scale in all age-appropriate gross motor skills *(von Baeyer 2009 [4b], Williamson 2005 [5a])*
- Ability to participate with self-report of pain less than or equal to 2 out of 10 on Numeric Rating Scale in all desired recreational activities *(von Baeyer 2009 [4b], Williamson 2005 [5a])*
- A minimum of 4+/5 strength for all core and lower extremity musculature bilaterally including hip flexors and extensors, hip abductors and adductors, hip internal and external rotators, knee flexors and extensors, ankle dorsiflexors and plantarflexors, lateral and medial ankle musculature
- Ability to demonstrate safe and proper alignment of trunk, hips, knees and feet while performing walking, lunging, squatting, jumping and running activities

Risks and Limitations for the patients in following this guideline include:

- Underlying concomitant tissue damage such as chondral lesions that can lead to long-term pain or loose bodies in the joint may lead to limitations or difficulties with full implementation of these guidelines
- Pre-disposing anatomical abnormalities may reduce a patient's chances for long-term success of the implementation of these guidelines to reduce lateral patellar instability

Background

Patellofemoral joint stability is sustained through complex and dynamic interactions among static, passive and active anatomical restraints and healthy biomechanics at the knee *(Balcarek 2011 [4b], Senavongse 2005 [4b], Mulford 2007 [5b], Beasley 2004 [5b])*. Due to these complex relationships, any anatomical variations, abnormal biomechanical tendencies, or a combination of both may compromise patellofemoral joint stability. In order to better understand the etiology of lateral PPD and RPI, it is helpful to review the general anatomic and biomechanical characteristics of a normal, healthy knee.

In a normal, healthy knee, the medial patellofemoral ligament (MPFL) serves as a passive stabilizer of the patella against lateralization during the first 20-30 degrees of knee flexion and helps guide the patella into the trochlear groove *(Philippot 2012b [4b], Amis 2003 [5b])*. Beginning around 20-30 degrees of knee flexion, the patella engages within the trochlear groove of the femur, which provides additional static support against lateralization of the patella *(Smith 2010b [1b], Philippot 2012b [4b], Mulford 2007 [5b])*. As the knee moves toward 90 degrees of flexion, the MPFL is further supported by other passive restraints including the patellar tendon, medial patellomeniscal ligament (MPML), and the medial patellotibial ligament (MPTL) *(Philippot 2012b [4b])*.

An active contraction of the quadriceps muscle group, which has fascial connections to the MPFL via the vastus medialis oblique (VMO), is frequently identified as a potential active stabilizer for the patella that helps guide the patella appropriately into the trochlear groove *(Brunet 2003 [4b], Farahmand 1998 [4b], Amis 2003 [5b])*. In addition to the quadriceps muscle group acting as an active stabilizer, dynamic coordinated muscle activations proximally at the trunk, pelvis and hip, and distally at the ankle and foot, can also influence the stability of the patellofemoral joint *(Souza 2010 [4b], Powers 2003 [4b], Powers 2010 [5a])*.

Table 1: Primary Stabilizers for Patellofemoral Joint

Type of Stabilizer	Primary Examples
Passive	• MPFL • Trochlear Groove Congruency • MPML • MPTL
Active	• Quadriceps muscle group
Coordinated Multi-Joint Muscle Activity	• Trunk • Pelvis • Hip • Ankle Foot

(Philippot 2012a [4b], Balcarek 2010 [4b], Souza 2010 [4b], Senavongse 2005 [4b], Brunet 2003 [4b], Powers 2003 [4b], Farahmand 1998 [4b], LocalConsensus 2013 [5], Mulford 2007 [5b], Beasley 2004 [5b], Amis 2003 [5b])

Primary Patellar Dislocation/Subluxation (PPD)

PPD Incidence

Epidemiological studies estimate an annual incidence of 107 per 100,000 acute primary dislocations each year in children ages 9-15 *(Nietosvaara 1994 [3b])* and between 2.29 and 11.19 per 100,000 each year for all other age groups *(Atkin 2000 [3b]) (Fithian 2004 [2a], Waterman 2012 [3a])*. Incidence of PPD is known to be highest among relatively active, young individuals between about 10 and 17 years of age *(Fithian 2004 [2a], Atkin 2000 [3b])*. Some sources have described a near equal rate of PPD for both males and females *(Stefancin 2007 [1b], Waterman 2012 [3a], Atkin 2000 [3b], Hinton 2003 [5b])*. Other epidemiological studies indicate that females, particularly girls under the age of 17, experience higher rates of primary dislocations *(Fithian 2004 [2a])*. The variability in the reported differences in incidences between sexes may relate to sampling bias and/or the confounding influences of age *(Fithian 2004 [2a])*, maturation *(Quatman-Yates 2013 [2a], Nikku 2009 [4b])* and activity levels *(Fithian 2004 [2a], Atkin 2000 [3b], LocalConsensus 2013 [5])*.

PPD Presentation

A patient with PPD may present to his or her healthcare provider with some or all of the following signs and symptoms *(Malanga 2003 [1b], Senavongse 2005 [4b], LocalConsensus 2013 [5], Slabaugh 2010 [5a], Mulford 2007 [5b], Beasley 2004 [5b])*:

- Reportable injury event
- Pain
- Inability to bear weight on involved limb
- Complaints of instability/giving way
- Moderate to large effusion
- Decreased ROM
- Impaired muscle activation and strength
- Limited ability to participate in ADLs and recreational activities

PPD Prognosis

Although in many cases, conservative management of PPD has been shown to be successful, patellar re-dislocation and recurrent instability symptom rates associated with PPD for all ages have been reported up to 52% and 50% respectively *(Stefancin 2007 [1b], Shea 2006 [5b])*. Evidence indicates that there is an increased risk for re-dislocation at a younger age, with a 60% re-dislocation rate for children aged 11-14 years old compared to a 33% re-dislocation incidence rate in patients 15-18 years of age. Additional factors that may negatively affect prognosis include the presence of osteochondral lesions and/or presence of significant damage to the medial stabilizers of the patella *(Stefancin 2007 [1b])*.

Recurrent Patellar Instability (RPI)

RPI Incidence

Annual incidence of RPI is less clear than the incidence for PPD as few epidemiologic studies have been performed on this injury type. Many studies have not clearly delineated between recurrent instability resulting from prior traumatic dislocations and cases with a traumatic or insidious onsets *(Smith 2010b [1b], Fithian 2004 [2a])*. One of the strongest predictors for recurrent instability is a prior history of PPD on either the previously involved or the uninvolved knee *(Fithian 2004 [2a], Palmu 2008 [2b])*. Higher rates of RPI have been reported for females *(Fithian 2004 [2a])* and for those who report a family history of patellar instability *(Fithian 2004 [2a], Palmu 2008 [2b])*.

RPI Presentation

Patients with RPI may present with signs and symptoms that are similar to patients with PPD. Patients with RPI may or may not have a past history of PPD, and they often present with signs and symptoms that are more chronic in nature. Additional signs and symptoms may include:

- Pain specifically localized to the patellofemoral joint *(Fithian 2004 [2a], LocalConsensus 2013 [5], Wilk 1998 [5a])*
- Minimal to no swelling/effusion *(Fithian 2004 [2a], LocalConsensus 2013 [5])*
- Self-limited participation in ADLs and recreational activities *(Stefancin 2007 [1b], LocalConsensus 2013 [5], Wilk 1998 [5a])*
- Excessive patellar mobility *(Stefancin 2007 [1b], Fithian 2004 [2a], LocalConsensus 2013 [5], Wilk 1998 [5a])*
- Patellar maltracking/subluxation *(Stefancin 2007 [1b], Fithian 2004 [2a], LocalConsensus 2013 [5], Wilk 1998 [5a])*

RPI Prognosis

There is some evidence to suggest that fewer injuries to soft tissue structures may occur with RPI incidents in comparison to patients with a PPD *(Fithian 2004 [2a])*. As many as 91% of patients with RPI managed conservatively, later report continued subjective sensations of subluxation or general feelings of patellofemoral instability *(Palmu 2008 [2b])*. The risk of PPD or RPI in the contralateral knee is relatively high in this group *(Fithian 2004 [2a], Palmu 2008 [2b])*.

Etiology

It is well acknowledged that the patella is most vulnerable to dislocation or subluxation in the first 20-30 degrees of flexion prior to engagement within the trochlear groove *(Philippot 2012b [4b], Amis 2003 [5b])*. Most lateral subluxations and dislocations occur when the knee is in a relatively extended position *(Nikku 2009 [4b], Senavongse 2005 [4b])*. The specific mechanisms associated with lateral PPD and RPI stem from a variety of factors such as underlying anatomic variations, abnormal structural alignment, and biomechanical deficiencies.

<u>PPD</u>

PPD Mechanism of Injury

PPD injuries can be categorized into two types of mechanisms: direct (contact) and indirect (non-contact). Direct injuries stem from an object or body that comes into direct contact with the medial patella and results in a lateral displacement of the patella *(Garth 1996 [4b], Shea 2006 [5b])*. Indirect, or non-contact injuries, stem from alterations in anatomical alignment, abnormal biomechanical forces, or a combination of both factors *(Fithian 2004 [2a], Ward 2007 [4a], Powers 2003 [5a])*. The net effect of these alterations may be an increase in lateralization of the patella with relation to the trochlear groove, resulting in an increased likelihood of subluxation and/or dislocation *(Ward 2007 [4a], Powers 2003 [5a])*.

Most PPD injuries, regardless of type, occur in the closed kinematic chain when moving from knee extension into knee flexion *(Nikku 2009 [4b])*. The specific mechanisms for non-contact PPD have not been well studied, many theorize that PPD injuries frequently occur when the foot is planted while the knee is in about 20-30 degrees of flexion, the tibia is externally rotated, and the femur is internally rotated, creating a position of knee valgus *(Atkin 2000 [3b], Visuri 2002 [4b], Garth 1996 [4b], Wilk 1998 [5a], Shea 2006 [5b], Hinton 2003 [5b], Bharam 2002 [?])*. The position of dynamic knee valgus (see Figure 1) places a high strain on the medial restraints of the patella and is associated with lateral patellar dislocation *(Senavongse 2005 [4b], Powers 2003 [5a], Amis 2003 [5b])*. This movement pattern commonly occurs in pivoting and cutting sporting activities, as well as during common activities of daily living (ADL's) *(Atkin 2000 [3b], Garth 1996 [4b])*.

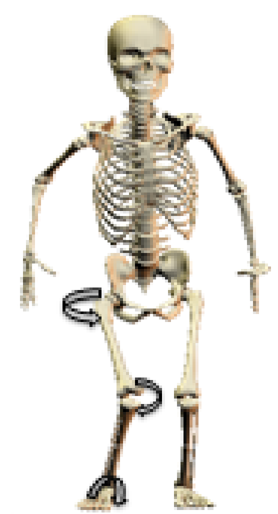

Figure 1. Dynamic Knee Valgus Position *(Thomas 2013 [5])*

PPD Anatomical Considerations

Abnormalities in patellofemoral joint shape affecting the risk of PPD include trochlear dysplasia and patellar dysplasia. Trochlear dysplasia is any abnormal shape of the distal femur where it aligns with the patella *(Panni 2011 [4b])*. Patellar dysplasia can similarly be defined as abnormal shape of the patellar facets where they align with the distal femur. Both forms of dysplasia can interfere with the patellofemoral joint's ability to act as a static restraint against patellar lateralization *(Panni 2011 [4b])*. For example, reduced depth of the trochlear groove may result in decreased height of the lateral femoral condyle resulting in altered patellofemoral joint stability.

Other patellofemoral joint abnormalities that can affect the risk of PPD due to altered ability to provide restraint and congruency for the arthrokinematics of the patellofemoral joint include: patella alta, high sulcus angle, high Laurin angle, and patellar overhang *(Balcarek 2011 [4a], Balcarek 2010 [4b])*. In the instance of patella alta, the patella is positioned higher than normal. It engages in the trochlear groove at higher degrees of knee flexion, which increases the ROM in which the patella is most vulnerable for lateralization *(Fithian 2004 [2a], Ward 2007 [4a])*. Sulcus and Laurin angles are radiographic measures that help provide further information about the shape and orientation of the patellofemoral joint. For more information on these terms, see Appendix 1.

Abnormalities in tibiofemoral joint alignment can also increase the risk of PPD. For example, high Q-angle and altered tibial tuberosity to trochlear groove (TT-TG) distance are associated with increased risk for PPD *(Atkin 2000 [3b], Panni 2011 [4b], Visuri 2002 [4b], Garth 1996 [4b], Greiwe 2010 [5b], Hinton 2003 [5b])*. The Quadriceps angle, or Q-angle, can be measured from the anterior superior iliac spine to the center of the patella, to the center of the tibial tubercle *(Rauh 2007 [4a])*. The TT-TG distance can be measured on radiograph in millimeters, from the tibial tuberosity to the center of the trochlear groove *(Panni 2011 [4b])*. In patients with a high Q-angle (> 20 degrees) and/or a high TT-TG distance (> 20 mm), the line of pull of the quadriceps muscle group through the patella is altered, resulting in an abnormal lateralization of the patella during active movement *(Rauh 2007 [4a], Panni 2011 [4b])*. For more information on these terms, see Appendix 1.

PPD Biomechanical Considerations

Although specific biomechanical risk factors for PPD have not been well-studied, the commonly cited mechanisms for non-contact PPD injuries are very similar to a number of other common traumatic knee injuries *(Waterman 2012 [3a])*, particularly to indirect/non-contact anterior cruciate ligament (ACL) knee injuries *(Hewett 2005 [2a])*. Like PPD, first-time ACL injuries most often occur during non-contact activities with the knee in a position of dynamic valgus similar to the position shown in Figure 1 *(Hewett 2005 [2a], Ford 2003 [4a], Powers 2003 [5a])*. Therefore, it may be appropriate to draw some additional inferences regarding potential biomechanical risk factors for PPD from the biomechanics of ACL injury, which has been studied much more extensively *(LocalConsensus 2013 [5])*.

With first-time ACL injuries, a number of biomechanical risk factors have been associated with landing in a valgus knee position. For example lower extremity weakness, reduced recruitment of the proximal gluteal musculature, reduced recruitment of the hamstrings relative to the quadriceps musculature and decreased proprioception of the trunk have all been associated with increased knee valgus position during landing *(Zazulak 2005 [4a], Malinzak 2001 [4a])*. Studies have found an association between pubertal maturation and the development of these risk factors, particularly for females *(Quatman-Yates 2013 [2a], Ford 2010 [4a], Hewett 2009 [4b])*. Given the higher incidence for PPD in female adolescents around the expected timing of pubertal maturation (ages 10-17), it is possible that PPD follows a similar pattern *(LocalConsensus 2013 [5])*.

<u>RPI</u>

RPI Mechanisms of Injury and Risk Factors

The etiology for RPI is very similar to PPD. For example, a number of anatomic morphological variations (e.g., trochlear and patellar dysplasia, high sulcus angles) and anatomical alignment variations (e.g., patella alta, Q-angle, increased TT-TG distance, high Laurin angles) have all been associated with increased incidence of RPI *(Fithian 2004 [2a], Atkin 2000 [3b], Balcarek 2011 [4b], Panni 2011 [4b], Balcarek 2010 [4b], Garth 1996 [4b], Greiwe 2010 [5b], Hinton 2003 [5b])*. Although the biomechanical factors that contribute to RPI have also not been sufficiently studied, the biomechanical risk factors for RPI are theorized to be similar to factors associated with PPD. A position of 20-30 degrees of knee flexion, external rotation of the tibia and internal rotation of the femur are likely positions of risk for RPI *(LocalConsensus 2013 [5])*.

Unlike PPD which is associated with a traumatic event, RPI is more commonly associated with multiple episodes of pain/or giving way *(Hinton 2003 [5b])* that can occur while simply performing ADLs *(Fithian 2004 [2a])*. Evidence indicates that patients who exhibit signs of joint hypermobility may also be at increased risk of RPI *(Garth 1996 [4b])*. With such predisposing factors as anatomic variations and/or joint hypermobility, patients with RPI may have relatively unstable patellae in general, making them more susceptible to injury with low-level abnormally directed forces and joint angles *(Ward 2007 [4a], LocalConsensus 2013 [5])*.

Guideline Recommendations

General Recommendations

1. It is recommended that patients begin physical therapy upon diagnosis of PPD or RPI in order to minimize secondary impairments such as persistent gait abnormalities, ROM deficits, and muscle atrophy that can result from poor gait patterns, immobility and disuse *(LocalConsensus 2013 [5])*.
2. It is recommended that throughout the diagnosis and rehabilitation process, physical therapists are in open communication with the referring physician and any other team members involved in order to promote the best, most efficient and optimally effective quality of care *(LocalConsensus 2013 [5], American Physical Therapy 2003 [5a])*.
3. It is recommended that the patient and family members receive thorough education regarding the nature of injury, the plan of care, and the risks for future injury *(LocalConsensus 2013 [5], American Physical Therapy 2003 [5a])*.

   Note: When educating the patient and family, it may be necessary to provide additional education about any factors specific to the patient that could potentially affect the patient's rehabilitation process and long-term prognosis. For example, if the patient has any anatomical abnormalities (e.g., patella alta), the clinician may want to inform the patient and family about the increased likelihood for re-occurrence of the injury relative to someone with PPD or RPI who does not have any anatomical variations *(LocalConsensus 2013 [5])*.
4. It is recommended that the referring physician is notified if any of the following red flags/precautions are present during the initial evaluation or at any other time during the rehabilitation process:
   - Signs of deep vein thrombosis *(LocalConsensus 2013 [5])*
   - Unchanging or increased irritability in the knee *(LocalConsensus 2013 [5])*
   - Persistent or recurrent effusion *(Stefancin 2007 [1b], LocalConsensus 2013 [5])*
   - Unexpected loss or minimal progression of ROM *(LocalConsensus 2013 [5])*
   - Catching, locking, or persistent pathological end feel with passive ROM *(Stefancin 2007 [1b], LocalConsensus 2013 [5])*.

   Note: It is estimated that approximately 20% to 40% of the PPD patient population suffer concomitant symptomatic osteochondral injuries *(Nietosvaara 1994 [3b])* and up to 95% of patients with RPI possess chondral lesions *(Slabaugh 2010 [5a])*. Therefore, if at any point during the rehabilitation, a patient experiences catching, locking or a persistent pathological end feel with passive ROM, the physical therapist may need to consider the possibility that an underlying chondral lesion or loose body could be present *(LocalConsensus 2013 [5])*.

Initial Examination

5. It is recommended that a thorough chart review is performed that includes review of general medical history and imaging studies (e.g., radiograph, CT scan, MR images) with an emphasis on identifying conditions or potential complications such as:
   - Trochlear dysplasia
   - Patellar dysplasia
   - Osteochondral defects
   - Soft tissue disruptions or abnormalities (e.g., MPFL tear)
   - Bone bruises

   Note: See appendix 1 for descriptions for additional measures for radiographic images *(LocalConsensus 2013 [5], American Physical Therapy 2003 [5a])*
6. It is recommended that pain is assessed and localized using an appropriate scale *(LocalConsensus 2013 [5])*.

   Note: The Oucher/Faces Pain Scale can be used with children 4-16 years of age *(Beyer 2005 [4a])* or the Numerical Rating Scale (NRS) can be used with children age 6 years and older and adults *(von Baeyer 2009 [4b], Williamson 2005 [5a])*.
7. It is recommended that a thorough history including the following information is obtained from the patient and/or family:
   - Age
   - Sex
   - Previous activity level

- Prior history of other musculoskeletal injuries and health conditions
- Patient and family history of patellar dislocation and hypermobility
- Description of mechanism of injury
- Description of prior/current treatment
- Complaints of "giving way"/feeling of instability
- Brace use
- Medications
- Weight-bearing status
- Restrictions/precautions
- Patient/family goals
- Date of next follow up visit with referring physician

(Stefancin 2007 [1b], LocalConsensus 2013 [5], American Physical Therapy 2003 [5a], Wilk 1998 [5a], Andrish 2008 [5b]).

8. It is recommended that a comprehensive objective physical therapy examination be completed, including the components named in Table 2 *(LocalConsensus 2013 [5], American Physical Therapy 2003 [5a])*.

Table 2: Initial Exam

Initial Exam	
Palpation	Palpated the following structures to localize pain sources and structural involvement: • Medial retinacular soft tissue structures • Adductor tubercle (Basset's Sign) • Bony landmarks of the patella • Lateral femoral condyle • Medial femoral condyle • Medial and lateral tibiofemoral joint lines • Patellar tendon • Tibial tuberosity • Tibial plateau • Peri-patellar spaces • General patellar region with active ROM to evaluate for crepitus *(LocalConsensus 2013 [5]).*
Girth	Obtain girth measurements via a tape measure to quantify edema and atrophy *(Slaa 2011 [4b]).* **Note:** It is common for girth to be smaller around the quadriceps region, indicating quadriceps atrophy, and bigger around joint lines indicating effusion *(LocalConsensus 2013 [5]).*
Range of Motion and Flexibility	Evaluate lower extremity passive ROM (PROM), active ROM (AROM) and flexibility for all lower extremity joints (hip, knee, and ankle) using a fluid filled goniometer or linear goniometer as appropriate *(Rao 2001 [4b], Watkins 1991 [4b]).* • Hip flexion, extension, abduction, adduction, internal rotation and external rotation • Knee flexion and extension • Ankle plantarflexion and dorsiflexion • Any other motions that appear to be functionally limited *(LocalConsensus 2013 [5]).*
Muscle Strength and Control	Perform muscle testing using manual muscle testing, hand-held dynamometry, and isokinetic testing as available and appropriate for the following: • Hip flexors, extensors, abductors, adductors, internal rotators and external rotators • Knee extensors and flexors • Ankle plantarflexors • Any other muscle group that appears to be functionally limited *(LocalConsensus 2013 [5])*
Special Tests	See Appendix 2 for descriptions of available tests clinicians can use to evaluate PPD/RPI.
Standing Alignment	Assess standing alignment with regard to: • Patella orientation (e.g., patella alta) • Extent of internal/external rotation of the femur and tibia • Genu valgus/varus • Genu recurvatum • Standing Q-angle • Extent of ankle pronation *(LocalConsensus 2013 [5])*
Balance/Gait	Evaluate gait with regard to: • Ability to bear weight on each limb • Ability to ambulate safely on even and uneven surfaces with least restrictive device and/or brace • Excessive internal rotation of femur during stance • Excessive hip drop during stance • Decreased terminal knee extension during stance and/or quadriceps avoidance gait pattern • Decreased push-off during transition from stance to swing phase • Decreased knee and hip flexion during

Initial Exam	
	swing phase • Decreased step length • Appropriate timing of activation of trunk, hip and lower extremity musculature *(LocalConsensus 2013 [5])*.
Functional Tests	Evaluate the following functional abilities as safe and appropriate: • Bed mobility and transfers • Double leg and single leg squat • Stair negotiation • Running • Single and double leg jumping *(Stefancin 2007 [1b], Smith 2011 [4b], LocalConsensus 2013 [5])*.

9. It is recommended that a comprehensive knee screen is performed to evaluate for additional conditions or complications of other important bony and soft tissue structures such as:
   - Anterior Cruciate Ligament
   - Posterior Cruciate Ligament
   - Medial Collateral Ligament
   - Lateral Collateral Ligament
   - Menisci

   (LocalConsensus 2013 [5]).

10. It is recommended that joint hypermobility be assessed to determine potential ligamentous laxity as an associated risk factor *(LocalConsensus 2013 [5])*.

    Note: The Beighton Scale is commonly used and cited to quantify hypermobility *(Smith 2008 [1b], Smits-Engelsman 2011 [3b], Cameron 2010 [3b], VanderGiessen 2001 [4b]).* (see Appendix 2)

11. It is recommended that knee-specific scales in conjunction with general health instruments are used for a more thorough understanding of the patient's assessment of his or her own knee function and general function after RPI/PPD, which may include:
    - Knee specific Instruments:
      - IKDC / Pedi-IKDC
      - Kujala Patellofemoral Disorder Score
      - Lysholm
      - Tegner Activity Score
      - Fulkerson
    - General Health Instruments:
      - Short Form 36
      - Musculoskeletal Function Assessment
      - PedsQL

    (Smith 2010a [1b], Smith 2008 [1b], Paxton 2003 [2a], Briggs 2009 [3b], LocalConsensus 2013 [5], Lysholm 2007 [5a]).

    Note: There is conflicting evidence regarding whether specific outcome measures directly pertaining to patellar instability are clinically meaningful *(Smith 2010b [1b])*. Nonetheless, studies indicate that the IKDC, Kujala, Fulkerson, Lysholm, and Tegner scales have all been demonstrated to have acceptable test–retest reliability, with a coefficient ranging from 0.82 to 0.92. With respect to validity, the Fulkerson, Kujala, Lysholm and IKDC were all able to differentiate statistically between a first time dislocation group and that with a history of subluxation / dislocation ($p<0.01$). The Kujala and IKDC instruments had the highest internal consistencies of the knee-specific instruments (Cronbach alpha, >0.80). The test-retest coefficients of all knee-specific scales exceeded 0.80; yielding high reliability *(Paxton 2003 [2a])*.

Patient and Family Centered Care

12. It is recommended that self-management education and skill building include tailored health education based on individual patient/family needs, risks, and readiness to change.

    Note: Self-management is the ability of the client and family to collaborate on and adhere to individualized therapy treatment recommendations and appropriately handle signs/symptoms/difficulties associated with the therapy and diagnosis to maximize quality of life and participation in life roles *(LocalConsensus 2013 [5], Lorig 2003 [5b])*.

13. It is recommended that the patient and family's ability to participate in the management of their condition is assessed with regard to:
    - Attitudes and beliefs, including confidence and importance *(Williams 2007 [3a])*
    - Readiness to change *(LocalConsensus 2013 [5])*.

14. I it is recommended that in order to develop an individualized and collaborative plan of care, the following things patient and family are considered:
    - understanding of the condition
    - self-efficacy, beliefs and stage of readiness to address the condition
    - degree of goal alignment with the health care team's goals
    - dynamics and access to resources to adhere to health care professionals' recommendations regarding the condition
    - potential barriers to being able to optimally attend physical therapy sessions and perform a home exercise program (HEP)

    (LocalConsensus 2013 [5], Ryan 2009 [5a], Holman 2004 [5b]).

Physical Therapy Assessment and Diagnosis

15. It is recommended that clinicians synthesize subjective, objective and self-management information from the physical therapy examination to establish a physical therapy diagnosis and individualize a plan of care *(American Physical Therapy 2003 [5a])*.

Re-Assessment

16. It is recommended that quantitative and qualitative measures be re-assessed approximately every two weeks and/or at any point the patient experiences a significant change in status *(LocalConsensus 2013 [5])*.

Management Recommendations

17. It is recommended that physical therapy dosage be determined based upon the patients' needs, preferences and specific impairments and supplemented with a HEP *(Friedrich 1996 [2b], LocalConsensus 2013 [5], Bailes 2008 [5a])*.

    Note: Patients who participate in supervised clinical visits demonstrate greater gains in muscle strength, functional mobility, gait speed, and quality of exercise performance than those who receive a HEP alone or no instruction at all *(Friedrich 1996 [2b])*.

18. It is recommended that a functional-based goal progression model of advancement through the phases of rehabilitation be followed rather than a time-based progression model *(LocalConsensus 2013 [5])*.

    Note 1: All recommended milestones/goals may not be appropriate for every individual; appropriate rehabilitation progression relies on sound clinical judgment, a good understanding of the patient's pre-injury level of function and personal activity goals *(LocalConsensus 2013 [5])*.

    Note 2: Appendix 3a-d provides a general overview of exercise and rehabilitation intervention suggestions that may be appropriate for each phase *(LocalConsensus 2013 [5])*.

Phases of Rehabilitation

General Interventions for All Phases

19. It is recommended that the following are performed for pain relief assistance as appropriate and necessary:
    - Cryotherapy *(Rice 2009 [2a], Hopkins 2006 [2a], Singh 2001 [2a], Bolgla 2000 [5b])*
    - Electrical stimulation and/or transcutaneous electrical nerve stimulation (TENS) per clinician discretion *(LocalConsensus 2013 [5], Palmieri-Smith 2008 [5a])*
    - Medications: Patients may be further encouraged to follow physician recommendations regarding taking pain-relieving medications *(LocalConsensus 2013 [5])*.

Effusion

20. It is recommended that the following are used as available and appropriate for edema management:
    - Cryotherapy *(Rice 2009 [2a], Hopkins 2006 [2a], Singh 2001 [2a], Bolgla 2000 [5b])*
    - Vasopneumatic device *(Holwerda 2012 [3b])*
    - Elastic compression wrap before and after therapy sessions *(Janwantanakul 2006 [4b], LocalConsensus 2013 [5])*

Initial Phase

This phase is designed to help patients prepare to engage in activities that will restore their ability to perform basic tasks associated with normalizing ROM and gait. Table 3 highlights the specific goals and expected outcomes for the Initial Phase. Appendix 3a provides a list of example exercises that may be appropriate for the Initial Phase. Some patients may skip this phase all together if, upon presentation, the goals/criteria for progression to the next phase have already been met *(LocalConsensus 2013 [5])*.

Table 3: Goals and Expected Outcomes for Initial Phase

Impairment	Goals
Pain	• ≤ 2 of 10 on NRS or little to no indication of pain with other scales during ambulation with or without assistive device as appropriate
Effusion	• Minimal
ROM/Flexibility	• 50% or greater relative to the uninvolved limb
Muscle Strength and Control	• Demonstrate sufficient activation of quadriceps femoris muscle group by performing a straight leg raise with minimal to no extensor lag for at least one straight leg raise • MMT score of at least 4/5 for abdominal muscles and all lower extremity musculature in the uninvolved leg
Balance	• Demonstrate symmetrical weight bearing in double limb stance with minimal to no assist
Gait	• Demonstrate independent, safe and normal walking mechanics with appropriate use of assistive device as needed
Functional Tasks	• Demonstrate safe and independent transfers, bed mobility and stair navigation with an assistive device as needed

(LocalConsensus 2013 [5])

Initial Phase--ROM/Flexibility

21. It is recommended that passive static stretches for lower extremity musculature are utilized to assist with gains in ROM and flexibility *(Moseley 2005 [2a], Bandy 1998 [2a], Davis 2005 [2b], LocalConsensus 2013 [5])*.

    Note 1: Gradual progression of (ROM) will help minimize the negative side effects of pain elevation, muscle guarding, and joint inflammation *(LocalConsensus 2013 [5])*.

    Note 2: For patients with PPD, ROM may take longer to normalize secondary to the traumatic mechanism of injury *(LocalConsensus 2013 [5])*.

    Note 3: Dynamic ROM and active assistive ROM (AAROM) may be helpful if the patient is muscle guarding due to pain and unable to achieve end range motion with static stretch *(Bandy 1998 [2a], LocalConsensus 2013 [5])*.

22. It is recommended that AROM and AAROM are performed following stretching to maintain new gains in motion *(Depino 2000 [2b])*.

Initial Phase--Muscle Strength and Control

23. It is recommended that strengthening exercises for this phase begin with isometric and isotonic exercises targeting hip and knee musculature in gravity-mitigated positions with progression to isotonic exercises against gravity as tolerated by patient *(LocalConsensus 2013 [5])*.

    Note 1: Isometric holds in varying degrees of hip flexion, hip abduction, and hip extension with the knee in full extension may help target key muscles while minimizing patellofemoral forces to limit pain *(LocalConsensus 2013 [5])*.

    Note 2: The addition of resistance to exercises and integration of eccentric-specific exercises may be appropriate for certain muscle groups and/or positions based on clinical judgment *(LocalConsensus 2013 [5])*.

    Note 3: Clinicians may want to avoid isokinetic exercises during this phase of treatment to minimize pain and risk for further injury *(LocalConsensus 2013 [5])*.

24. It is recommended that exercises are initiated with 2 sets of 10-15 repetitions of exercises as appropriate, with progression to 3 sets of each exercise as tolerated *(Rhea 2002 [2b], Faigenbaum 1996 [4b], LocalConsensus 2013 [5])*.

    Note: If the patient is unable to perform 2 sets of 10 repetitions of an exercise, the intensity of the exercise may be modified per clinical judgment *(LocalConsensus 2013 [5])*.

25. It is recommended that visual, tactile and verbal feedback cues be provided as needed to ensure optimal performance for all exercises in every rehabilitation phase *(Nikku 2009 [4b])*.

    Note: Individuals who receive regular positive feedback from a physical therapist are more likely to be adherent with a supplemental HEP *(Sluijs 1993 [4b])*.

26. It is recommended that Neuromuscular Electrical Stimulation (NMES) be used in conjunction with exercise to facilitate quadriceps activation and

strength *(Fithian 2004 [2a], Snyder-Mackler 1995 [2a], LocalConsensus 2013 [5])*.

27. It is recommended that additional isometric and isotonic strengthening exercises are implemented to target bilateral core and hip musculature *(Powers 2010 [5a], Reinold 2006 [5a])*.

Initial Phase--Balance

28. It is recommended that balance exercises begin with an emphasis on symmetrical weight bearing in double limb stance with minimal to no assist and progressed to good control with weight-shifting in Anterior-Posterior and Medial-Lateral directions *(LocalConsensus 2013 [5])*.

    Note: Weight shifting in the anterior-posterior and medial-lateral directions may help to prepare the patient to progress away from dependence on an assistive device and help the patient progress to single leg balance in the next rehabilitation phase *(LocalConsensus 2013 [5])*.

Initial Phase--Gait

29. It is recommended that patient-specific ambulation exercises are implemented to improve the patient's ability to:
    - Weight bear as tolerated and appropriate per physician recommendation
    - Demonstrate adequate ROM in hip, knee and ankle at each phase of the gait cycle
    - Maintain good quadriceps control, particularly during stance phase
    - Decrease dependence on assistive device while maintaining good gait mechanics *(LocalConsensus 2013 [5])*.

Initial Phase--Functional Tasks

30. It recommended that the patient is provided training and education in bed mobility, transfers and safe stair navigation with progression toward minimal use of assistive device as appropriate *(LocalConsensus 2013 [5])*.

Restoring Basic Function Phase

The purpose of this phase is to ensure the patient is able to perform all basic functional tasks associated with typical activities of daily living (e.g., walking longer distances, stooping, and stair navigation) *(LocalConsensus 2013 [5])*. The specific goals and expected outcomes for the Restoring Basic Function Phase are listed in Table 4. Appendix 3b provides a list of example exercises that may be appropriate for the Restoring Basic Function Phase.

Table 4: Goals and Expected Outcomes for Basic Function Phase

Impairment	Goals
Pain	• ≤2 of 10 on NRS or little pain to no pain as indicated by other pain scale with all basic functional tasks
Effusion	• Intermittent to minimal
ROM/Flexibility	• 90% or greater relative to the uninvolved limb
Muscle Strength and Control	• Ability to maintain an unassisted straight leg raise without an extensor lag for 10 seconds • Manual muscle testing strength (MMT) of at least 4-/5 for the hip, knee, and ankle musculature of the involved limb or 60-65% of isometric dynamometer comparison to uninvolved • MMT strength of at least 4+/5 for core muscles and uninvolved hip, knee and ankle musculature • Demonstrate a double leg squat with good alignment with minimal visual, tactile or verbal cues
Balance	• Single leg balance to 90% timed performance of uninvolved limb on stable surface
Gait	• Demonstrate normal walking mechanics without the use of assistive device on even and uneven surfaces
Functional Tasks	• Demonstrate safe and independent transfers, bed mobility and stair navigation (with reciprocal stepping) without the use of an assistive device • Demonstrate quick unanticipated change of direction while ambulating
Cardiovascular	• Tolerate 5 minutes of minimal intensity activity such as walking or low resistance stationary cycling
Patient Reported Outcome Measure (IKDC, Kujala, Peds QL)	• At 60% of goal target

(LocalConsensus 2013 [5])

Restoring Basic Function Phase--ROM/Flexibility

31. It is recommended that passive static stretches for lower extremity musculature continue to be utilized to assist with gains in ROM and flexibility

(Moseley 2005 [2a], Bandy 1998 [2a], Davis 2005 [2b], LocalConsensus 2013 [5]).

Note: Dynamic ROM *(Bandy 1998 [2a])* may continue to be appropriate if the patient is muscle guarding due to pain and unable to achieve end range motion with static stretch *(LocalConsensus 2013 [5])*.

32. It is recommended that AROM and AAROM continue to be performed following stretching to maintain new gains in motion *(Depino 2000 [2b])*.

Restoring Basic Function Phase--Muscle Strength and Control

33. It is recommended that strengthening exercises include resisted isometric and isotonic strengthening exercises (concentric and eccentric) specifically targeting the hip, knee and ankle musculature of the involved limb *(Bolgla 2005 [4b], LocalConsensus 2013 [5], Powers 2010 [5a], Reinold 2006 [5a])*.

    Note 1: Isokinetic exercises may be appropriate to integrate in the later stages of this phase *(LocalConsensus 2013 [5])*.

    Note 2: It may be necessary to begin these exercises with lighter resistance (partial to body weight only) with progression to increased resistance per clinical judgment *(Bolgla 2005 [4b], LocalConsensus 2013 [5])*.

34. It is recommended that Neuromuscular Electrical Stimulation (NMES) continue to be used as needed in conjunction with exercise to facilitate quadriceps activation and strength *(Fithian 2004 [2a], Snyder-Mackler 1995 [2a], LocalConsensus 2013 [5])*.

35. It is recommended that Open Kinetic Chain Exercises (OKCE) are incorporated into the strength training exercises for the involved limb *(Escamilla 1998 [4b], LocalConsensus 2013 [5])*.

    Note: For patients with patellofemoral pain and/or concomitant chondral lesions, it may be necessary to limit knee flexion ROM per clinical judgment to minimize pain or discomfort *(Souza 2010 [4b], LocalConsensus 2013 [5])*.

36. It is recommended that isotonic OKCE for knee flexion/extension are initially performed from 90-40 degrees for the involved limb to allow for enhanced osseous stability with progressions working toward exercises throughout the entire ROM *(Escamilla 1998 [4b], LocalConsensus 2013 [5])*.

37. It is recommended that isotonic Closed Kinetic Chain Exercises (CKCE) are initiated using a double limb stance with a focus on neuromuscular control of the pelvis, femur, tibia, and patella during knee flexion ROM to encourage optimal alignment of all joints during movements *(LocalConsensus 2013 [5])*.

    Note 1: The initiation of single limb CKCE can begin per clinician discretion, with emphasis on patient's ability to demonstrate sufficient neuromuscular control to maintain good alignment of lower extremity throughout the activity *(LocalConsensus 2013 [5])*.

    Note 2: The following exercises can effectively target the quadriceps muscle group during the Restoring Basic Function Phase:

    - forward step ups,
    - lateral step ups,
    - retro/reverse step ups,
    - and wall squats

    (Lubahn 2011 [4a], Ayotte 2007 [4a], Boren 2011 [4b], Mercer 2009 [4b]).

    Note 3: Exercises that can effectively target the gluteus medius during this phase of rehabilitation:

    - double leg squat,
    - wall squat, forward step-up,
    - lateral step-up, side stepping
    - and side plank

    (Ayotte 2007 [4a], Boren 2011 [4b], Distefano 2009 [4b], Mercer 2009 [4b], Ekstrom 2007 [4b], LocalConsensus 2013 [5]).

    Note 4: Exercises that can be utilized to target the gluteus maximus:

    - double leg squat
    - forward step-up
    - lateral step-up
    - retro/reverse step-up
    - quadruped alternating upper extremity/lower extremity extension,
    - forward lunges
    - wall squat

    (Lubahn 2011 [4a], Ayotte 2007 [4a], Boren 2011 [4b], Mercer 2009 [4b], Ekstrom 2007 [4b]).

38. It is recommended that a continued emphasis is placed on targeting hip, knee and ankle musculature of the uninvolved limb and any other muscle groups (e.g., core and trunk musculature) where significant strength deficits remain present *(Bolgla 2005 [4b], Powers 2010 [5a], Reinold 2006 [5a])*.

    Note: Specific exercises that can effectively target core abdominal musculature include the following:

    - swiss ball roll-outs,
    - swiss ball skier,
    - swiss ball knee-up

    (Escamilla 1998 [4b]).

Restoring Basic Function Phase--Balance

39. It is recommended that balance exercises for this phase include double limb stance challenges on dynamic surfaces and other external perturbations with an emphasis on transitioning to the ability to safely balance independently on a single leg.

    Note: Patients at this stage may also be ready to begin more challenging single leg balance challenges that include unstable surfaces and external perturbations.
    (LocalConsensus 2013 [5])

Restoring Basic Function Phase--Gait

40. It is recommended that the remaining deficits in the gait cycle (e.g., quadriceps avoidance) continue to be emphasized to progress the patient off any assistive devices and normalize gait patterns on even and uneven surfaces *(LocalConsensus 2013 [5])*.

Restoring Basic Function Phase--Functional Tasks

41. It is recommended that for activities of daily living advanced training exercises such as the following be incorporated:

    - repeated chair squats,
    - reciprocal stair climbing and single leg balance with floor touches or object pick-ups
    - obstacle avoidance and quick changes/pivots in direction while ambulating

    (LocalConsensus 2013 [5]).

Restoring Basic Function Phase--Cardiovascular

42. It is recommended that minimal intensity cardiovascular exercise be performed at a Rate of Perceived Exertion (RPE) of 9-11 on the 6-20 Borg Scale or 3-4 on the Pictorial Children's Effort Rating Table (PCERT) *(Roemmich 2006 [4a], Dunbar 1992 [4b], LocalConsensus 2013 [5], Groslambert 2006 [5a])*.

    Note: RPE has been shown to be a valid and reliable measurement of exertion and correlated with heart rate produced during physical activity *(Dunbar 1992 [4b], Groslambert 2006 [5a])*.

Restoring Advanced Function Phase

The purpose of this phase is to fully restore the patient's ability to engage in pre-injury levels of function and build symmetry between involved and uninvolved limbs. See Table 5 for a list of specific goals and expected outcomes for the Restoring Advanced Function Phase. Appendix 3c provides a list of example exercises that may be appropriate for the Restoring Advanced Function Phase. By the end of this phase, patients should be able to meet the Center for Disease Control recommended guidelines for physical activity with the ability to participate in all activities expected for healthy, typically-developing children such as full participation in physical activity classes and at least 60 minutes of activity of moderate intensity (e.g. brisk walking) and vigorous intensity (e.g. running) a day *(LocalConsensus 2013 [5], DHHS 2008 [5a])*.

Table 5: Goals and Expected Outcomes for Advanced Function Phase

Impairment	Goals
Pain	• Resolved for all activities of daily living, recreational activities and age appropriate skills
Effusion	• Resolved for all activities
ROM/Flexibility	• Equal to uninvolved

Impairment	Goals
Muscle Strength and Control	• Manual muscle testing strength (MMT) of at least 4+/5 for involved limb hip, knee, and ankle musculature (or at least 85% of isometric dynamometer comparison to uninvolved) • MMT strength of 5/5 for core muscles and uninvolved hip, knee and ankle musculature • Perform double leg squat to 90 degrees of knee flexion with proper form and technique for 10 seconds • Perform single squat to 60 degrees of knee flexion with proper form and technique for 10 seconds • Perform planks/modified plank for 60 seconds • Perform side planks/modified side planks for 60 seconds • Perform Sorenson test for 60 seconds • Perform V-sit hold for 30 seconds
Balance	• Demonstrate single leg balance equal to uninvolved limb for time • Demonstrate single leg balance quality equal to uninvolved leg on unstable surfaces • Demonstrate good ability to balance on a single leg with internally derived (e.g. reaching for an object or tossing a ball) and externally derived perturbations (e.g., perturbations applied to wobble board by clinician) bilaterally
Gait	• Demonstrate good, symmetrical mechanics while running short distances at 50%, 75% and 100% pre-injury intensity levels (a minimum of 50')
Functional Tasks	• Demonstrate good ability to climb/navigate varying step heights or playground-type pieces of equipment safely • Demonstrate good mechanics while stooping, kneeling, lifting heavy objects • Demonstrate good mechanics while performing basic-level hopping, skipping, jumping, and jogging activities per age-appropriate activity-level needs • Demonstrate double leg jumping in place on static surfaces with proper technique 100% of the time for 10 jumps • Limb Symmetry index of $\geq$ 85 on all single leg hop tests

Impairment	Goals

Cardiovascular	• Demonstrate good ability to participate in cardiovascular activity without increased pain or adverse event (such as early onset of fatigue with regards to age and activity, syncope) greater than or equal to 90% intensity and duration of pre-injury level of function such as:
	  ○ walking,
	  ○ stationary cycling,
	  ○ swimming,
	  ○ skipping,
	  ○ jumping,
	  ○ running

Patient Reported Outcome Measure (IKDC, Kujala, Peds QL)	• At 85% of goal target

(LocalConsensus 2013 [5])

__Restoring Advanced Function Phase-- ROM/Flexibility__

43. It is recommended that passive static stretches for lower extremity musculature continue to be utilized to assist with gains and/or maintenance of good ROM and flexibility *(Moseley 2005 [2a], Bandy 1998 [2a], Davis 2005 [2b], LocalConsensus 2013 [5])*.

44. It is recommended that manual therapy techniques such as more aggressive manual stretching and joint mobilizations are utilized if ROM deficits continue to be present in the involved knee *(LocalConsensus 2013 [5])*.

__Restoring Advanced Function Phase-- Muscle Strength and Control__

45. It is recommended that isotonic and isokinetic resistance exercises targeting the knee, hip and ankle musculature of the involved knee continue to be integrated into therapeutic exercises *(LocalConsensus 2013 [5])*.

    Note: Level of resistance may be increased and increased ROM may be utilized for both OKCE and CKCE as tolerated by the patient and within the patient's ability to maintain good core, hip, knee and foot alignment *(LocalConsensus 2013 [5])*.

46. It is recommended that a continued emphasis is placed on good control, alignment and appropriate muscle recruitment for double leg and single leg activities with an increased number of repetitions and improved endurance with isometric holds *(LocalConsensus 2013 [5])*.

Note 1: Exercises emphasizing full-body dynamic movements in multiple planes of motion that incorporate strength and endurance building for core musculature and trunk stability *(Powers 2010 [5a], Reinold 2006 [5a], Greiwe 2010 [5b])* and strengthening activities performed on both static and dynamic surfaces can be particularly useful during the Restoring Advanced Function Phase *(LocalConsensus 2013 [5], Reinold 2006 [5a], Bolgla 2000 [5b])*.

Note 2: The following exercises can effectively target the gluteus medius:

- single leg squat
- single leg balance with hip abduction
- single leg bridges in supine
- single leg deadlifts
- side planks with hip abduction

(Lubahn 2011 [4a], Boren 2011 [4b], Distefano 2009 [4b], Ekstrom 2007 [4b], Bolgla 2005 [4b]).

Note 3: The following exercises can effectively target the gluteus maximus:

- single leg squat
- single leg bridge
- side plank with hip abduction
- front plank with hip extension
- single leg deadlift,
- transverse lunges

(Lubahn 2011 [4a], Boren 2011 [4b], Distefano 2009 [4b], Ekstrom 2007 [4b]).

Note 4: The following exercises can effectively target the core abdominal muscles:

- swiss ball pike
- swiss ball roll-out with hip extension
- front plank with hip extension
- side plank with hip abduction

(Boren 2011 [4b], Escamilla 1998 [4b]).

Restoring Advanced Function Phase-- Balance

47. It is recommended that balance training activities include more advanced activities for single leg balance with perturbations on unstable surfaces *(LocalConsensus 2013 [5])*.

Restoring Advanced Function Phase-- Gait

48. It is recommended that exercise interventions that emphasize good, symmetrical and safe gait patterns for jogging and running are integrated into this phase *(LocalConsensus 2013 [5])*.

    Note: Even if a patient did not engage in running activities regularly prior to injury, it is likely they may be expected to participate in at least low-level running activities for physical education classes or for participation at recess with classmates. Therefore, it is important to ensure the patient is able to run at least short distances safely using good form *(LocalConsensus 2013 [5])*.

Restoring Advanced Function Phase-- Functional Tasks

49. It is recommended that exercises are integrated that emphasize:

    - quick changes in direction on stable and unstable surfaces and even and uneven step-heights
    - that increase intensity and dynamic motions associated with ADLs or work/play related tasks (e.g. squatting or lunging quickly with heavier weight to replicate lifting heavier boxes/object from the floor) with emphasis on mechanics
    - age-appropriate activities such as skipping, double leg hopping, single leg hopping, skipping and jogging per patient and family goals and to return to desired physical activity

    (LocalConsensus 2013 [5]).

    Note: These exercises emphasize improving the patient's ability to fully participate in physical education class and/or in recreational activities and are task or sport-specific such as being able to navigate the playground, participate in physical education classes or engage in the work environment safely.

    (LocalConsensus 2013 [5]).

Restoring Advanced Function Phase-- Cardiovascular

50. It is recommended that moderate intensity cardiovascular exercises are integrated with a RPE of 12-14 on the 6-20 Borg Scale or 5-6 on the PCERT and vigorous intensity exercise be performed with a RPE of 15-17 or 7-8 on the

PCERT *(Roemmich 2006 [4a], Dunbar 1992 [4b], LocalConsensus 2013 [5], Groslambert 2006 [5a])*.

Return-to-Activity Phase

Successful attainment of the goals for the Restoring Advanced Function Phase is used as indication of the individual's readiness to reintegrate into higher level activities. If the patient's highest level of personal functional goals have been met at this time, and clinical judgment dictates the patient is able to perform all age-appropriate types of activities (e.g., full participation in physical education classes), it may appropriate to discharge patient at this time. Appendix 3d provides a list of example exercises that may be useful for the Return-to-Activity Phase.

51. It is recommended that progressive reintegration into activities be conducted according to the Evidence-based Care Guideline for Return-to-Activity After Lower Extremity Injury *(LocalConsensus 2013 [5], Schmitt 2010 [5a])*.

Discharge Criteria

52. It is recommended that discharge from therapy be based on clinical judgment, attainment of goals, and successful participation in desired activities *(LocalConsensus 2013 [5])*.

Future Research Agenda

Due to limited evidence in the current literature, many of the recommendations provided in this guideline were based on low-level evidence and/or local consensus of the authorship team. Specific suggestions for future research to help improve the evidence regarding conservative management of lateral instability in children, adolescents and young adults include:

1. Incidence of PPD and RPI classified by associated risk factors (e.g., anatomic abnormalities), activity levels, maturational levels and gender.
2. Studies regarding tissue healing properties following PPD and RPI.
3. Epidemiological reports describing typical presentation of PPD and RPI.
4. Creation and validation of a patellar instability scale appropriate for children and adolescents.
5. Determine the effectiveness of current and recommended rehabilitation approaches to maximize outcomes and minimize risk of secondary injury for children and adolescents with lateral patellar instability.

Appendix 1: Relevant Radiographic Measures Related to Patellofemoral Joint

Measurement	Definition	References
Assessment for Patella Alta	Ratio of patellar height to patellar tendon higher than 1.0 - 1.3	*(Atkin 2000 [3b], Panni 2011 [4b], Garth 1996 [4b])*
Sulcus Angle	Defined as the angle formed by the highest points on the medial and lateral femoral condyles and the lowest point of the intercondylar groove/sulcus	*(Atkin 2000 [3b], Garth 1996 [4b])*
Laurin Angle	Measure of two lines, one joining the peaks of the trochlear groove, the other tangential to the lateral slope of the patella, measured in 20 degrees of knee flexion on axial films, an angle less than or equal to 0 degrees is considered abnormal	*(Atkin 2000 [3b])*
Patella Overhang	Defined by a perpendicular line from the lateral border of the patella to the femoral condyles with any portion lateral to the femoral condyle being measured in millimeters	*(Atkin 2000 [3b])*
Patellar Tilt	Measured as the average angle of the patella with quadriceps contracted and relaxed at full knee extension and 15 degrees of knee flexion, with greater than 20 degrees considered pathological	*(Panni 2011 [4b])*
Q angle	Angle between the line of the extensor apparatus (quad) and the line of the patellar tendon	*(Garth 1996 [4b])*
TT-TG distance	Measured as the distance between the tibial tuberosity and the trochlear groove and normally measures less than 20 mm on films	*(Balcarek 2011 [4b], Panni 2011 [4b])*

Appendix 2: Examination Tests for PPD/RPI

Test	Description	References
Patellar Tilt	Patient spine, knee relaxed in full extension or 20 degrees of flexion. Examiner holds the patella between their thumb and forefinger, and pushes the patella down in an attempt to flip the lateral edge of the patella upwards. Elevation of the lateral patella to less than neutral suggests an abnormal result, where 0 to 20° elevation is normal. Limited upwards movement may indicate excessively tight lateral retinaculum, as normally the patella can be tilted upwards above horizontal.	*(Smith 2008 [1b])*
Patellar Glide	Patient spine, knee in full extension, or 30 degrees of knee flexion. Patella manually glided medially and laterally. The patella is divided into 4 quadrants. A glide greater than or equal to 3 quadrants (or more than half the patellar width) represents reduced patella restraint. Excessive glide suggests reduced restraint from the medial structures or tightness of the lateral retinaculum. One study recommends a patella stability tester be used to quantify lateral glide (Egusa, 2010 [4a])	*(Smith 2008 [1b], Smith 2012 [3b], Egusa 2010 [4a], Smith 2011 [4b])*
Apprehension Test	Patient supine, knee relaxed in 30° flexion. Examiner uses one hand to push the patella laterally. A positive sign is when it reproduces the patient's pain or causes fear that the patella will dislocate. Apprehension can either be from verbal expression of anxiety, and/or involuntary quadriceps muscle contraction. Reduced medial stability allows excessive lateral glide to mimic a recurrent dislocation.	*(Smith 2008 [1b], Smith 2012 [3b], Smith 2011 [4b])*
Modified Apprehension Test	Patient supine, knee relaxed in 30° flexion, neutral rotation. Examiner applies a force to the superior border of the patella in a distal and lateral direction at 45° (i.e. in the direction of the fibular head). This force would reduce the tension of the distally based medial patellomeniscal ligament to isolate the MPFL. In addition, a distal force would prevent the anterior prominence of the proximal lateral femoral sulcus from inhibiting lateral translation to isolate a disruption of the MPFL.	*(Smith 2008 [1b], Tanner 2003 [4a])*

Appendix 2: Examination Tests for PPD/RPI Continued

Moving Apprehension Test	Begins with the knee held in full extension and the patella is manually translated laterally with the thumb. The knee is then flexed to 90° and then brought back to full extension while the lateral force on the patella is maintained. For the second half of the test, the knee is started in full extension, brought to 90° of flexion, and then back to full extension while the index finger is used to translate the patella medially. For a positive test in part 1, the patient orally expresses apprehension and may activate his or her quadriceps in response to apprehension. In part 2, the patient experiences no apprehension and allows free flexion and extension of the knee (*sensitivity of 100%, a specificity of 88.4%, a positive predictive value of 89.2%, a negative predictive value of 100%, and an accuracy of 94.1%.100% sensitive, and 88% specific) (Ahmad,2009 [4b]).*	*(Ahmad 2009 [4b])*
Hypermobility criteria **(Beighton–Horan Assessment)**	5 areas are assessed on the body: passive hyperextension of 5th finger (0-2pts); passive thumb opposition to the forearm (0-2pts); active elbow hyperextension of more than 10 degrees (0-2pts); knee hyperextension in standing of more than 10 degrees (0-2pts); standing trunk flexion with palms of hands touching the ground (0-1pt). Each of the 5 areas is scored bilaterally, except for standing trunk flexion, with a maximum of 9 points if each side of the body displays hypermobility. A score of 4 or more on the Beighton Scale is often considered a diagnostic criterion for benign joint hypermobility syndrome.	*(Smith 2008 [1b], Smits-Engelsman 2011 [3b], Cameron 2010 [3b], VanderGiessen 2001 [4b])*
Q angle	With the patient supine or standing, a line is drawn from the anterior superior iliac spine, to the center of the patella. A second line is then drawn from the center of the patella to the tibial tubercle. The angle this makes is the Q-angle. Normal value is 10 to 15° for men and 15 to 20° for women. Increased Q-angle may increase the laterally directed force on the extensor mechanism, predisposing the patella to mal-positioning and instability.	*(Smith 2008 [1b])*

Appendix 2: Examination Tests for PPD/RPI Continued

Patellar Tracking Test (J-sign)	Patient sits on the edge of the plinth, knee in full extension. Patient then actively moves the knee into full flexion. Examiner observes for an exaggerated lateral to medial translation of the patella into the trochlear groove in early flexion. This may suggest excessively tight lateral retinaculum, causing the patella to shift laterally in terminal knee extension as it disengages from the femoral intertrochlear groove. This is frequently associated with patella alta or trochlear dysplasia (Andrish, 2008 [5b]). "Clinical subluxation is substantially more common in the non-traumatic group, and may suggest underlying predisposing factors that need to be recognized and potentially addressed, especially if re-dislocation occurs "(Larsen, 1982 [3b]). Moderate agreement between therapists (K=.53), low intra observer agreement (K=.28) (Smith, 2012 [3b]).	*(Smith 2008 [1b], Smith 2012 [3b], Smith 2011 [4b])*
Bassett's Sign	Tenderness to palpation of the adductor tubercle and medial epicondyle- may indicate a rupture of disruption of the MPFL contributing to reduced medial stability of the patella (*sensitivity 70% good intra-observer agreement K=.76)* (*Smith, 2012 [3b]).*	*(Smith 2008 [1b], Smith 2012 [3b], Smith 2011 [4b])*
Tibial Tubercle to Trochlear Groove (TTTG) Assessment	Patient in semi-recumbent position. Mid-point of the symphysis pubis and the anterior superior iliac spine are marked. This is the proximal reference point. Knee in 90° flexion, a caliper is applied across the epicondyles. One end of a piece of string is held by the patient over the reference point, and where the caliper and string meet, is the centre of the trochlear groove. The string is then positioned over the front of the knee and confirmed to be straight by visually inspection. The horizontal distance is then measured between the string to the centre of the tibial tubercle. The knee is then fully extended whilst the string is pulled taught inline with the proximal reference point. Once the knee is in full extension, the horizontal distance between the string and the tibial tubercle is measured with a ruler. A displacement lateral to the string is a positive, and medial is a negative score. The score is the displacement of the tubercle in extension from the flexion measurement. **Indication:** The TTTG suggests the position of the tibial tubercle relative to the patella. This may indicate whether the tubercle is lateralized which could increase the lateral force on the patella.	*(Smith 2008 [1b])*

Appendix 3a: Intervention Examples for the Initial Phase *(LocalConsensus 2013 [5])*

ROM/Flexibility	Muscle Strength, Neuromuscular Control and Gait	Cardiovascular	Other
1. Partial to full revolutions on stationary bike to improve ROM 2. Knee flexion stretch 3. Knee extension stretch 4. Gastrocnemius and soleus stretches 5. Mobilization of patella all directions except lateral	1. Quadriceps isometric sets 2. Gluteal isometric sets 3. Side lying straight leg raises for hip flexion, abduction, adduction and extension 4. Clamshells 5. Long arc quadriceps sets 6. Mini squats with table assist 7. Double leg bridges 8. Theraband exercises for involved ankle 9. Anterior-posterior weight shifts 10. Medial-lateral weight shifts 11. Prone planks	1. Walking for increased distances as tolerated and appropriate 2. Upper body ergometer as tolerated 3. Walking in a pool as tolerated and appropriate	1. Electrical stimulation for managing pain and effusion 2. Cryotherapy for managing pain and effusion 3. Vasopneumatic device and/or compression wraps for managing effusion 4. NMES to facilitate quadriceps activation

Appendix 3b: Intervention Examples for the Restoring Basic Function Phase *(LocalConsensus 2013 [5])*

ROM/Flexibility	Muscle Strength, Neuromuscular Control and Gait	Cardiovascular	Other
1. Full revolutions on stationary bike to maintain/improve ROM 2. Knee flexion stretch 3. Knee extension stretch 4. Gastrocnemius and soleus stretches 5. Mobilization of patella all directions except lateral	1. Straight leg raises for hip flexion, abduction, adduction, and extension with added resistance and isometric holds as tolerated and appropriate 2. Double leg squats 3. Forward step-ups 4. Lateral step-ups 5. Retro/Reverse step-ups 6. Wall squats 7. Hamstring curls 8. Leg press 9. Sidesteps 10. Calf raises 11. Double leg dynamic balance (unstable surfaces, rocker board, ball toss) 12. Single leg balance on firm surface 13. Prone planks 14. Side planks 15. Stability ball roll-outs 16. Stability ball knee-up	1. Upper body ergometer 2. Initiate stationary biking for conditioning; increasing resistance as tolerated and appropriate 3. Marches, forward, retro, lateral stepping in pool 4. Swimming	1. Electrical stimulation for managing pain and effusion 2. Cryotherapy for managing pain and effusion 3. Vasopneumatic device and/or compression wraps for managing effusion 4. Neuromuscular Electrical Stimulation to facilitate quadriceps activation

Appendix 3c: Intervention Examples for the Restoring Advanced Function Phase *(LocalConsensus 2013 [5])*

ROM/Flexibility	Muscle Strength, Neuromuscular Control and Gait	Cardiovascular
1. Stretches as needed to maintain ROM and flexibility	1. Forward step up (high) 2. Lateral step up (high) 3. Reverse step up (high) 4. Wall squat 5. Double Leg squat 0°-90° 6. Single Leg squat 0°-45° 7. Side plank 8. Single Leg balance + hip abduction 9. Single Leg bridge 10. Side stepping 11. Resisted diagonal stepping 12. Quadruped alternating Upper Extremity/Lower Extremity 13. Forward lunge and add trunk rotation as appropriate to challenge stability 14. Retro lunge 15. Stability ball roll-out 16. Stability ball skier 17. Stability ball knee up 18. Anterior step down 19. Prone and lateral planks 20. Dynamic balancing double leg and single leg (reactive and anticipatory) 21. Double leg ankle hops (vertical, medial/lateral, anterior/posterior, diagonal) adding height and distance as appropriate 22. Double leg mini squat jumps (focusing on form and adding height/distance as appropriate) 23. Initiating low-level Single leg hops 24. Agility ladder drills	1. Stationary biking or elliptical trainer at progressively harder levels of intensity and longer periods of time 2. Swimming-start with pulling and advance to using lower extremity at progressively harder levels of intensity and longer periods of time 3. Run/walk program with progression to running at desired intensity level as appropriate

Appendix 3d: Intervention Examples for the Return-to-Activity Phase *(LocalConsensus 2013 [5])*

ROM/Flexibility	Muscle Strength, Neuromuscular Control and Gait	Cardiovascular
1. Stretches as needed to maintain range of motion and flexibility	1. Single Leg squat 0°-45° 2. Side plank + hip abduction 3. Front plank + hip abduction 4. Front plank + hip extension 5. Single Leg deadlift 6. Transverse lunge 7. Multi planar lunges 8. Stability Ball pike up 9. Progressing previous exercises with increased holds, repetitions, or intensity as appropriate 10. Sport specific drills and activities 11. Box drops 12. Box jump with rebound 13. Double Leg plyojumps A/P and M/L- progressing height and quickness as appropriate 14. Double Leg jumping (squat jumps, lunge jumps, alternating lunge jumps) 15. Double Leg bounding jumps 16. Single Leg static jumping 17. Single Leg anterior-posterior, medial-lateral and diagonal plyojumps	1. Elliptical Trainer 2. Jogging and/or running 3. Sprinting 4. Plyometrics 5. Cutting and pivoting activities

Members of Conservative Physical Therapy Management of Lateral Patellar Instability Team 2013

Division of Occupational Therapy and Physical Therapy Guideline Development Team

Catherine C. Quatman-Yates, PT, DPT, PhD, Team Leader, Division of Occupational Therapy and Physical Therapy and Department of Pediatrics Division of Sports

Amber Boyd, PT, DPT, SCS, CSCS, Division of Occupational Therapy and Physical Therapy

Jason Hugentobler, PT, DPT, SCS, CSCS, Division of Occupational Therapy and Physical Therapy

Kathleen Hugentobler PT, DPT, CSCS, Division of Occupational Therapy and Physical Therapy

Jeffery A. Taylor-Haas, PT, DPT, OCS, CSCS, Division of Occupational Therapy and Physical Therapy

Meredith Sheaffer, PT, DPT, CSCS, Division of Occupational Therapy and Physical Therapy

Senior Clinical Director

Rebecca D. Reder OTD, OTR/L, Division of Occupational Therapy and Physical Therapy

Ad Hoc Assistants

***During student affiliations at Cincinnati Children'**

Jamie Curley, PT, DPT, CSCS

Christopher Wall, PT, DPT, CSCS

Ashley Hemm, SPT

Alison Roell, SPT Laura Neal, PT, DPT

Marti Bradbury, PT, DPT

Kadi Carmisino, SPT

Internal Advisors

Chad Cherny, PT, DPT, MS, SCS, CSCS, , Division of Occupational Therapy and Physical Therapy

Julie Lee, PT, DPT, Division of Occupational Therapy and Physical Therapy

Robyn McHugh, PT, OCS, Division of Occupational Therapy and Physical Therapy

Ad hoc Advisors

Michelle Kiger, MHS, OTR/L, Division of Occupational Therapy and Physical Therapy

Mark Paterno, PT, PhD, MBA, SCS, ATC Division of Occupational Therapy and Physical Therapy

Karen Vonderhaar, Anderson Center

Support

Mary Gilene, MBA, Division of Occupational Therapy and Physical Therapy

Karen Vonderhaar, Anderson Center

All of the staff listed above have signed a conflict of interest declaration and none were found

Development Process

The process by which this guideline was developed is documented in the Guideline Development Process Manual; relevant development materials are kept electronically. The recommendations contained in this guideline were formulated by an interdisciplinary working group which performed systematic search and critical appraisal of the literature, using the Table of Evidence Levels described following the references, and examined current local clinical practices. The recommendation statements were formally reviewed by other physical therapists, physicians and athletic trainers. In addition, specific feedback regarding patient and family needs and preferences were obtained through a review process with former patients and family members who have undergone conservative management of lateral patellar instability.

To select evidence for critical appraisal by the group for this guideline, the Medline, EmBase and the Cochrane databases were searched for dates of October 23, 2013 to generate an unrefined, “combined evidence” database using a search strategy focused on answering clinical questions relevant to patellar instability and employing a combination of Boolean searching on human-indexed thesaurus terms (MeSH headings using an OVID Medline interface) and “natural language” searching on words in the title, abstract, and indexing terms. The key words used were: “Patellar Instability,” “Patellar instability,” “Patellar Dislocation,” “Patella Dislocation,” “Medial Patellofemoral Ligament,” “MPFL,” “Patellar Subluxation”, and “Patellar Subluxation.”. The citations were reduced by: eliminating duplicates, review articles, non-English articles, and adult articles. The resulting abstracts were reviewed by team members to eliminate low quality and irrelevant citations. During the course of the guideline development, additional clinical questions were generated and subjected to the search process, and some relevant review articles were identified. September 18, 2013 was the last date for which literature was reviewed for the previous version of this guideline. The details of that review strategy are not documented. However, all previous citations were reviewed for appropriateness to this revision.

Tools to assist in the effective dissemination and implementation of the guideline may be available online at http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm . Experience with the implementation of earlier publications of this guideline has provided learnings which have been incorporated into this revision.

Once the guideline has been in place for five years, the development team reconvenes to explore the continued validity of the guideline. This phase can be initiated at any point that evidence indicates a critical change is needed.

Recommendations have been formulated by a consensus process directed by best evidence, patient and family preference and clinical expertise. During formulation of these recommendations, the team members have remained cognizant of controversies and disagreements over the management of these patients. They have tried to resolve controversial issues by consensus where possible and, when not possible, to offer optional approaches to care in the form of information that includes best supporting evidence of efficacy for alternative choices.

The guideline has been reviewed and approved by clinical experts not involved in the development process, distributed to senior management, and other parties as appropriate to their intended purposes.

The guideline was developed without external funding. All Team Members and Anderson Center support staff listed have declared whether they have any conflict of interest and none were identified.

Copies of this Evidence-based Care Guideline (EBCG) and any available implementation tools are available online and may be distributed by any organization for the global purpose of improving child health outcomes. Website address:

http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm. Examples of approved uses of the EBCG include the following:

- copies may be provided to anyone involved in the organization's process for developing and implementing evidence based care guidelines
- hyperlinks to the CCHMC website may be placed on the organization's website
- the EBCG may be adopted or adapted for use within the organization, provided that CCHMC receives appropriate attribution on all written or electronic documents
- copies may be provided to patients and the clinicians who manage their care.

Notification of CCHMC at HPCEInfo@cchmc.org for any EBCG, or its companion documents, adopted, adapted, implemented or hyperlinked by the organization is appreciated.

NOTE: These recommendations result from review of literature and practices current at the time of their formulations. This guideline does not preclude using care modalities proven efficacious in studies published subsequent to the current revision of this document. This document is not intended to impose standards of care preventing selective variances from the recommendations to meet the specific and unique requirements of individual patients. Adherence to this guideline is voluntary. The clinician in light of the individual circumstances presented by the patient must make the ultimate judgment regarding the priority of any specific procedure.

For more information about this guideline, its' supporting evidences and the guideline development process, contact the James M. Anderson Center for Health Systems Excellence office at EBDMInfo@cchmc.org .

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Note: When using the electronic version of this document, ☜ indicates a hyperlink to the PubMed abstract.

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Note: Full tables of evidence grading system available in separate document:

- Table of Evidence Levels of Individual Studies by Domain, Study Design, & Quality (abbreviated table below)
- Grading a Body of Evidence to Answer a Clinical Question
- Judging the Strength of a Recommendation (abbreviated table below)

Table of Evidence Levels (see note above)

Quality level	***Definition***
1a† or 1b†	Systematic review, meta-analysis, or meta-synthesis of multiple studies
2a or 2b	Best study design for domain
3a or 3b	Fair study design for domain
4a or 4b	Weak study design for domain
5a or 5b	Other: General review, expert opinion, case report, consensus report, or guideline
5	Local Consensus

†a = good quality study; b = lesser quality study

Table of Recommendation Strength (see note above)

Strength	***Definition***
"Strongly recommended"	There is consensus that benefits clearly outweigh risks and burdens (or visa-versa for negative recommendations).
"Recommended"	There is consensus that benefits are closely balanced with risks and burdens.
No recommendation made	There is lack of consensus to direct development of a recommendation.

Dimensions: In determining the strength of a recommendation, the development group makes a considered judgment in a consensus process that incorporates critically appraised evidence, clinical experience, and other dimensions as listed below.

1. Grade of the Body of Evidence (see note above)
2. Safety / Harm
3. Health benefit to patient *(direct benefit)*
4. Burden to patient of adherence to recommendation *(cost, hassle, discomfort, pain, motivation, ability to adhere, time)*
5. Cost-effectiveness to healthcare system *(balance of cost / savings of resources, staff time, and supplies based on published studies or onsite analysis)*
6. Directness *(the extent to which the body of evidence directly answers the clinical question [population/problem, intervention, comparison, outcome])*
7. Impact on morbidity/mortality or quality of life