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Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain

Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and Health from the Orthopaedic Section of the American Physical Therapy Association

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Recommendations*

RISK FACTORS: Clinicians should consider the shoe-surface interaction, increased body mass index, narrow femoral notch width, increased joint laxity, preovulatory phase of the menstrual cycle in females, combined loading pattern, and strong quadriceps activation during eccentric contractions as predisposing factors for the risk of sustaining a noncontact anterior cruciate ligament (ACL) injury. (Recommendation based on moderate evidence.)

DIAGNOSIS/CLASSIFICATION: Passive knee instability, joint pain, joint effusion, and movement coordination impairments are useful clinical findings for classifying a patient with knee instability into the following International Statistical Classification of Diseases and Related Health Problems (ICD) categories: Sprain and strain involving collateral ligament of knee, Sprain and strain involving cruciate ligament of knee, Injury to multiple structures of knee; and the associated International Classification of Functioning, Disability, and Health (ICF) impairment-based category of knee instability (b7150 Stability of a single joint) and movement coordination impairments (b7601 Control of complex voluntary movements). (Recommendation based on strong evidence.)

DIFFERENTIAL DIAGNOSIS: Clinicians should consider diagnostic classifications associated with serious pathological conditions or psychosocial factors when the patient's reported activity limitations or impairments of body function and structure are not consistent with those presented in the diagnosis/classification section of this guideline or when the patient's symptoms are not resolving with interventions aimed at normalization of the patient's impairments of body function. (Recommendation based on moderate evidence.)

EXAMINATION – OUTCOME MEASURES: Clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee stability and movement coordination impairments. These tools are useful for identifying a patient's baseline status relative to pain, function, and disability and for monitoring changes in the patient's status throughout the course of treatment. (Recommendation based on strong evidence.)

EXAMINATION – ACTIVITY LIMITATION MEASURES: Clinicians should utilize easily reproducible physical performance measures, such as single-limb hop tests, to assess activity limitation and participation restrictions associated with their patient's knee stability and movement coordination impairments, to assess the changes in the patient's level of function over the episode of care, and to classify and screen knee stability and movement coordination. (Recommendation based on weak evidence.)

INTERVENTIONS – CONTINUOUS PASSIVE MOTION: Clinicians can consider using continuous passive motion in the immediate postoperative period to decrease postoperative pain. (Recommendation based on weak evidence.)

INTERVENTIONS – EARLY WEIGHT BEARING: Early weight-bearing can be used for patients following ACL reconstruction without incurring detrimental effects on stability or function. (Recommendation based on weak evidence.)

INTERVENTIONS – KNEE BRACING: The use of functional knee bracing appears to be more beneficial than not using a brace in patients with ACL deficiency. (Recommendation based on weak evidence.) The use of immediate postoperative knee bracing appears to be no more beneficial than not using a brace in patients following ACL reconstruction. (Recommendation based on moderate evidence.) Conflicting evidence exists for the use of functional knee bracing in patients following ACL reconstruction. (Recommendation based on conflicting evidence.) Knee bracing can be used for patients with acute posterior cruciate ligament (PCL) injuries, severe medial collateral ligament (MCL) injuries, or posterior lateral corner (PLC) injuries. (Recommendation based on expert opinion.)

INTERVENTIONS – IMMEDIATE VERSUS DELAYED MOBILIZATION: Clinicians should consider the use of immediate mobilization following ACL reconstruction to increase range of motion, reduce pain, and limit adverse changes to soft tissue structures. (Recommendation based on moderate evidence.)

INTERVENTIONS – CRYOTHERAPY: Clinicians should consider the use of cryotherapy to reduce postoperative knee pain immediately post-ACL reconstruction. (Recommendation based on weak evidence.)

INTERVENTIONS – SUPERVISED REHABILITATION: Clinicians should consider the use of exercises as part of the in-clinic program, supplemented by a prescribed home-based program supervised by a physical therapist in patients with knee stability and movement coordination impairments. (Recommendation based on moderate evidence.)

INTERVENTIONS – THERAPEUTIC EXERCISES: Clinicians should consider the use of non–weight-bearing (open chain) exercises in conjunction with weight-bearing (closed chain) exercises in patients with knee stability and movement coordination impairments. (Recommendation based on strong evidence.)

INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION: Neuromuscular electrical stimulation can be used with patients following ACL reconstruction to increase quadriceps muscle strength. (Recommendation based on moderate evidence.)

INTERVENTIONS – NEUROMUSCULAR REEDUCATION: Clinicians should consider the use of neuromuscular training as a supplementary program to strength training in patients with knee stability and movement coordination impairments. (Recommendation based on moderate evidence.)

Recommendations* *(continued)*

INTERVENTIONS – "ACCELERATED" REHABILITATION: Rehabilitation that emphasizes early restoration of knee extension and early weight bearing activity appears safe for patients with ACL reconstruction. No evidence exists to determine the efficacy or safety of early return to sports. (Recommendation based on moderate evidence.)

INTERVENTIONS – ECCENTRIC STRENGTHENING: Clinicians should consider the use of an eccentric exercise ergometer in patients following ACL reconstruction to increase muscle strength and functional performance. Clinicians should consider the use of eccentric squat program in patients with PCL injury to increase muscle strength and functional performance. (Recommendation based on moderate evidence.)

*These recommendations and clinical practice guidelines are based on the scientific literature published prior to January 2009.

Introduction

AIM OF THE GUIDELINE

The Orthopaedic Section of the American Physical Therapy Association (APTA) has an ongoing effort to create evidence-based practice guidelines for orthopaedic physical therapy management of patients with musculoskeletal impairments described in the World Health Organization's International Classification of Functioning, Disability, and Health (ICF).[171]

The purposes of these clinical guidelines are to:

- Describe evidence-based physical therapy practice including diagnosis, prognosis, intervention, and assessment of outcome for musculoskeletal disorders commonly managed by orthopaedic physical therapists
- Classify and define common musculoskeletal conditions using the World Health Organization's terminology related to impairments of body function and body structure, activity limitations, and participation restrictions
- Identify interventions supported by current best evidence to address impairments of body function and structure, activity limitations, and participation restrictions associated with common musculoskeletal conditions
- Identify appropriate outcome measures to assess changes resulting from physical therapy interventions
- Provide a description to policy makers, using internationally accepted terminology, of the practice of orthopaedic physical therapists
- Provide information for payors and claims reviewers regarding the practice of orthopaedic physical therapy for common musculoskeletal conditions
- Create a reference publication for orthopaedic physical therapy clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of orthopaedic physical therapy

STATEMENT OF INTENT

This guideline is not intended to be construed or to serve as a standard of medical care. Standards of care are determined on the basis of all clinical data available for an individual patient and are subject to change as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered guidelines only. Adherence to them will not ensure a successful outcome in every patient, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular clinical procedure or treatment plan must be made in light of the clinical data presented by the patient, the diagnostic and treatment options available, and the patient's values, expectations, and preferences. However, we suggest that the rationale for significant departures from accepted guidelines be documented in the patient's medical records at the time the relevant clinical decision is made.

Methods

The Orthopaedic Section, APTA appointed content experts as developers and authors of clinical practice guidelines for musculoskeletal conditions of the knee which are commonly treated by physical therapists. These content experts were given the task to identify impairments of body function and structure, activity limitations, and participation restrictions, described using ICF terminology, that could (1) categorize patients into mutually exclusive impairment patterns upon which to base intervention strategies, and (2) serve as measures of changes in function over the course of an episode of care. The second task given to the content experts was to describe the supporting evidence for the identified impairment pattern classification as well as interventions for patients with activity limitations and impairments of body function and structure consistent with the identified impairment pattern classification. It was also acknowledged by the Orthopaedic Section, APTA content experts that a systematic search and review of the evidence solely related to diagnostic categories based on International Statistical Classification of Diseases and Health Related Problems (ICD)[171] terminology would not be useful for these ICF-based clinical practice guidelines as most of the evidence associated with changes in levels of impairment or function in homogeneous populations is not readily searchable using the ICD terminology. For this reason, the content experts were directed to also search the scientific literature related to classification, outcome measures, and intervention strategies for musculoskeletal conditions commonly treated by physical therapists. Thus, the authors of this clinical practice guideline systematically searched MEDLINE, CINAHL, and the Cochrane Database of Systematic Reviews (1966 through January 2009) for any relevant articles related to classification, outcome measures, and intervention strategies for ligament injuries and instabilities of the knee. Additionally, when relevant articles were identified their reference lists were hand-searched in an attempt to identify other articles that might have contributed to the outcome of these clinical practice guidelines.

This guideline was issued in 2010 based upon publications in the scientific literature prior to January 2009. This guideline will be considered for review in 2014, or sooner if new evidence becomes available. Any updates to the guideline in the interim period will be noted on the Orthopaedic Section of the APTA website: www.orthopt.org

LEVELS OF EVIDENCE

Individual clinical research articles were graded according to criteria described by the Center for Evidence-Based Medicine, Oxford, United Kingdom (http://www.cebm.net) for diagnostic, prospective, and therapeutic studies[122] (Table 1).

I	Evidence obtained from high-quality diagnostic studies, prospective studies, or randomized controlled trials
II	Evidence obtained from lesser-quality diagnostic studies, prospective studies, or, randomized controlled trials (eg, weaker diagnostic criteria and reference standards, improper randomization, no blinding, <80% follow-up)
III	Case controlled studies or retrospective studies
IV	Case series
V	Expert opinion

GRADES OF EVIDENCE

The overall strength of the evidence supporting recommendations made in this guideline were graded according to guidelines described by Guyatt et al[53] as modified by MacDermid and adopted by the coordinator and reviewers of this project. In this modified system, the typical A, B, C, and D grades of evidence have been modified to include the role of consensus expert opinion and basic science research to demonstrate biological or biomechanical plausibility (Table 2).

GRADES OF RECOMMENDATION BASED ON		STRENGTH OF EVIDENCE
A	Strong evidence	A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study
B	Moderate evidence	A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation
C	Weak evidence	A single level II study or a preponderance of level III and IV studies including statements of consensus by content experts support the recommendation
D	Conflicting evidence	Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting studies.
E	Theoretical/ foundational evidence	A preponderance of evidence from animal or cadaver studies, from conceptual models/principles or from basic sciences/bench research support this conclusion
F	Expert opinion	Best practice based on the clinical experience of the guidelines development team

Methods *(continued)*

REVIEW PROCESS

The Orthopaedic Section, APTA also selected consultants from the following areas to serve as reviewers of the early drafts of this clinical practice guideline:

- Claims review
- Coding
- Epidemiology
- Medical practice guidelines
- Orthopaedic physical therapy residency education
- Orthopaedic Section of the APTA, Inc
- Orthopaedic surgery
- Rheumatology
- Physical therapy academic education
- Sports physical therapy residency education

Comments from these reviewers were utilized by the authors to edit this clinical practice guideline prior to submitting it for publication to the *Journal of Orthopaedic & Sports Physical Therapy*.

CLASSIFICATION

The primary ICD-10 codes and conditions associated with knee stability and movement coordination impairments are S83.4 Sprain and strain involving (fibular)(tibial) collateral ligament of knee, S83.5 Sprain and strain involving (anterior)(posterior) cruciate ligament of knee, and S83.7 Injury to multiple structures of knee, Injury to (lateral)(medial) meniscus in combination with (collateral)(cruciate) ligaments. The corresponding ICD-9 CM codes and conditions, which are used in the USA are 717.83 Old disruption of anterior cruciate ligament, 717.84 Old disruption of posterior cruciate ligament, 717.85 Old disruption of other ligaments of knee, 844.0 Sprain of lateral collateral ligament of knee, 844.1 Sprain of medial collateral ligament of knee, and 844.2 Sprain of cruciate ligament of knee.

The primary ICF body functions codes associated with the above noted ICD-10 conditions are **b7150 Stability of a single joint** and **b7601 Control of complex voluntary movements.**

The primary ICF body structures codes associated with knee stability and movement coordination impairments are **s75011 Knee joint**, **s75002 Muscles of thigh, s75012 Muscles of lower leg**, and **s75018 Structure of lower leg, specified as ligaments of the knee.**

The primary ICF activities and participation codes associated with knee stability and movement coordination impairments are **d2302 Completing the daily routine** and **d4558 Moving around**, **specified as direction changes while walking or running**.

The ICD-10 and primary and secondary ICF codes associated with knee stability and movement coordination impairments are provided in Table 3.

ICD-10 and ICF Codes Associated With Knee Stability and Movement Coordination Impairments

INTERNATIONAL STATISTICAL CLASSIFICATION OF DISEASES AND RELATED HEALTH PROBLEMS		
Primary ICD-10	S83.4	Sprain and strain involving collateral ligament of knee
	S83.5	Sprain and strain involving cruciate ligament of knee
	S83.7	Injury to multiple structures of knee

INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY, AND HEALTH		
	PRIMARY ICF CODES	
Body functions	b7150	Stability of a single joint
	b7601	Control of complex voluntary movements
Body structure	s75011	Knee joint
	s75002	Muscles of thigh
	s75012	Muscles of lower leg
	s75018	Structure of lower leg, specified as ligaments of the knee
Activities and participation	d2302	Completing the daily routine
	d4558	Moving around, specified as direction changes while walking or running
	SECONDARY ICF CODES	
Body functions	b28016	Pain in joints
	b7100	Mobility of a single joint
	b7301	Power of muscles of one limb
	b7408	Muscle endurance functions, specified as endurance of muscles of one limb
	b770	Gait pattern functions (knee stability with walking and running)
Activities and participation	d4101	Squatting
	d4102	Kneeling
	d4106	Shifting the body's centre of gravity
	d4351	Kicking
	d4502	Walking on different surfaces
	d4503	Walking around obstacles
	d4551	Climbing
	d4552	Running
	d4553	Jumping
	d9201	Sports
Environmental factors	e1408	Products and technology for culture, recreation, and sport, specified as shoe-surface interaction and knee bracing

CLINICAL GUIDELINES

Impairment/Function-based Diagnosis

INCIDENCE

Anterior Cruciate Ligament It is estimated that 80 000 to 250 000 injuries occur to the anterior cruciate ligament (ACL) per year in the United States[44,50] with about 100 000 ACL reconstructions performed annually, the sixth most common orthopaedic procedure in the United States.[62] Approximately 70% of all ACL injuries are noncontact in nature and 30% are contact injuries.[57] The incidence of noncontact ACL injuries is greater in sports that require multidirectional activities, such as rapid deceleration, pivoting, cutting, and landing from jumps.[51] The incidence of ACL injuries was 20.3% of all athletic knee injuries over a period of 10 years.[96]

Female athletes sustain ACL injuries at a 2.4 to 9.7 times greater rate when compared to male athletes.[14,109] Prodromos et al[125] matched injuries to gender and sport and used weighted means to calculate the female to male ratios. The results for female to male ACL injury ratios were as follows: wrestling, 4.05; basketball, 3.5; indoor soccer, 2.77; soccer, 2.67; rugby, 1.94; lacrosse, 1.18; and alpine skiing, 1.00.

Beynnon et al,[14] in their comprehensive review, report that patients with an ACL-deficient knee may experience giving-way episodes and are more likely to develop meniscal tears and knee osteoarthritis. One study reports that the incidence of meniscal tears in patients with an ACL-deficient knee is 40% at year 1, 60% at year 5, and 80% 10 years after the index injury.[90]

Posterior Cruciate Ligament Depending on the clinical setting, the incidence of posterior cruciate ligament (PCL) injury is 0.65% to 44% of all ligamentous knee injuries.[49,96] The most common causes for PCL injury are motor vehicle accidents and athletics. It has been reported that patients who sustained a trauma have a higher incidence of PCL injuries than athletes.[37] Motorcycle accidents and soccer-related injuries accounted for the main specific injury causes.[139] In traffic accidents, 63.8% who were injured had a PCL injury with damage to additional ligaments, whereas, in athletic injuries, combined injuries represented 47.5% of injuries. Ninety-five percent of patients with PCL injuries have associated ligamentous injuries in the ipsilateral knee.[36]

Collateral Ligaments The incidence of medial (tibial) collateral ligament (MCL) lesions was 7.9% of all athletic injuries.[96] An injury to the MCL was the most common knee injury reported at the 2005 National Football League Combine[19] and in alpine skiing,[169] and second most in American collegiate men's ice hockey[43] and collegiate women's rugby.[90] Injury to the lateral (fibular) collateral ligament (LCL) is the least common of all knee ligament injuries with an incidence of 4%. Injury to the LCL usually occurs as a soft-tissue avulsion off the proximal attachment on the femur or as a bone avulsion associated with an arcuate fracture of the fibular head.[86,87] LCL injuries usually are part of more extensive injuries that involve the posterolateral corner (PLC).[87]

Multiple Ligaments Two of the most common multiligament knee injuries involve the MCL with the ACL, and the PLC with the ACL or the PCL. Halinen et al[54] reported an incidence of multiple ligament knee injuries of approximately 0.8/100 000 persons per year. If excessive valgus excursion injury occurs, in addition to an MCL rupture, the ACL may also tear, producing a more extensive injury.[123] Complete (grade III) MCL lesions have an almost 80% incidence of concomitant ligament damage, and 95% of the time, the torn ligament is the ACL.[38,54] The incidence of ACL tears was 20% when no valgus laxity was present on clinical exam, 53% when valgus laxity was present only when tested in 30° of knee flexion, and 78% when valgus laxity was present when tested in full knee extension.[123] Isolated PLC injuries account for only 1.6% of all knee ligament injuries with the incidence of concomitant ligament damage ranging from 43% to 80%.[8] Combined posterior instabilities were present in 53% of patients, with a significantly higher incidence after vehicular trauma (64%) compared to athletic injuries (46%).[139]

PATHOANATOMICAL FEATURES

Anterior Cruciate Ligament The ACL originates at the medial side of the lateral femoral condyle and runs an oblique course through the intercondylar fossa in a distoanteromedial direction to the insertion at the medial tibial eminence.[121] Girgis et al[48] divided the ACL into 2 functional bands, the anteromedial and posterolateral bundles. The ACL is the primary restraint to anterior translation of the tibia relative to the femur[22] and a major secondary restraint to internal rotation, particularly when the joint is near full extension.[34]

The most common region of an ACL tear occurs in the midsubstance of the ACL during low energy injuries as seen in sporting activities.[79,116]

Shimokochi and Shultz[148] performed a systematic review examining the mechanics of noncontact ACL injury, which included studies published through 2007. They concluded that noncontact ACL injuries are likely to happen during deceleration and acceleration motions with excessive quadriceps contraction and reduced hamstring co-contraction at or near full knee extension. ACL loading was higher during the application of a quadriceps force when combined with knee internal rotation, a valgus load combined with knee internal rotation, or excessive valgus knee loads applied during weight-bearing, decelerating activities.

Posterior Cruciate Ligament The PCL proximally attaches to the roof and medial aspect of the femoral intercondylar notch and distally attaches onto the superior aspect of the posterior tibial "shelf."[3] It is divided into 2 main fiber bundles: anterolateral and posteromedial. The PCL is the primary restraint to posterior tibial translation, contributing about 90% of the resistance across the knee flexion arc[3] and the secondary restraint to external rotation of the tibia on the femur.[74]

In a retrospective study by Schulz,[139] 587 patients with acute and chronic PCL-deficient knees were evaluated. Almost half of the patients were able to give a detailed history of the mechanism of injury. The most common injury mechanism was a "dashboard/anterior tibial blow injury" (38.5%), followed by a fall on the flexed knee with the foot in plantar flexion (24.6%), and lastly, a sudden violent hyperextension of the knee joint (11.9%).

Collateral Ligaments The MCL originates on the medial aspect of the femur, proximal and posterior to the medial femoral epicondyle, courses distally and attaches anterior to the posteromedial tibial crest and distal to the medial tibial plateau.[85] It can be divided into 3 tissue layers (superficial MCL, deep MCL, and posterior oblique ligament) and multiple interconnections to the joint capsule, the muscle-tendon units, and the medial meniscus.[123] In cadaver knee studies, the superficial MCL provided 57% of the restraining knee valgus moment at 5° of knee flexion, and provided 78% of the restraining moment at 25° of knee flexion, due to decreased contribution from the posterior capsule.[52] The vast majority of MCL injuries involve a sudden application of a valgus torque to the knee,[130] typically from a direct hit to the lateral aspect of the knee with the foot in contact with the ground.[67] Clinical and laboratory findings are in conflict whether the femoral insertion or tibial insertion is the most common site of MCL injury.[123]

The LCL attaches to the femur approximately equidistant from the posterior and distal borders of the lateral femoral condyle and distally to a superior and laterally facing V-shaped plateau on the head of the fibula.[108] It is the main structure responsible for resisting varus moments, particularly in the initial 0° to 30° of knee flexion, and has a role in limiting external rotation of a flexed knee.[52]

Posterolateral Corner The PLC consists of several structures, including the lateral head of the gastrocnemius, the popliteus tendon, the popliteofibular ligament, the LCL, and the arcuate ligament-fabellofibular ligament.[131] The PLC serves as the primary restraint to both varus and external rotation forces and the secondary restraint to posterior translation of the tibia on the femur. Isolated injury can occur from a posterolateral directed force to the proximal medial tibia with the knee at or near full extension, forcing the knee into hyperextension and varus. Combined PLC injuries can result from: knee hyperextension, external rotation, and varus rotation; complete knee dislocation; or a flexed and externally rotated knee that receives a posteriorly directed force to the tibia.[8,97,131]

CLINICAL COURSE

Anterior Cruciate Ligament Injuries Noyes et al[117] suggested that one-third of individuals with an ACL injury will compensate well and successfully return to unrestricted activities without surgery. Another third could return to recreational activities with knee bracing, a lower extremity strengthening program, and activity modification. The final third would not be able to return to sports due to knee instability and would require surgical intervention.

A meta-analysis by Muaidi et al[114] examined the clinical course of function to identify prognostic factors in the conservative management of individuals with an ACL-deficient knee. Self-reported measures of knee function utilizing the Lysholm or modified Lysholm knee score ranged from 75/100 at 60 months to 94/100 at 66 months. Activity level was measured using the Tegner scale with preinjury activity level of 7.1/10 and at follow-up between 12 and 66 months later it had decreased to 5.6/10.

Moksnes and Risberg[112] found at 1 year follow-up that patients who did not have surgery, had Knee Outcome Scale (KOS) scores of 94.4/100, global rating scale of knee function (GRS) of 85.3/100, and International Knee Documentation Committee Subjective Knee Form (IKDC-2000) of 86.1/100. Functional performance was measured using the single-limb single hop for distance test. Results of this test are usually expressed based on limb symmetry index (LSI). LSI is calculated by dividing the result of the involved limb by that of the uninvolved limb and multiplying by 100%. LSI was 87% to 93% preoperatively.[31,112] Others reported LSI values that were greater than 95% (normal values greater than 85%[9]) at a follow-up of between 12 and 55 months following postnonoperated injury.[112,114]

Kostogiannis et al[83] found that only 42% of the patients were able to resume their preinjury activity within 3 years following nonreconstructed ACL injury. The mean Lysholm knee score was 96, 95, and 86 at 1, 3, and 15 years after index injury, respectively. The mean Tegner activity scale decreased from 7 to 4, 15 years after the injury. Seventy-three percent of patients reported good/excellent results and 17% reported fair/poor function at 15 years.

Multiple case series reveal that conservative (nonoperative) management of patients with ACL-deficient knees can be effective for patients who are willing to avoid high-risk activities.[14] Nonoperative return to high-level activities based on patient self-selected basis has ranged from 23% to 42%.[63,83] A decision-making scheme developed by Fitzgerald et al[39] screened 93 consecutive patients with acute unilateral ACL ruptures, classifying them as either rehabilitation candidate (n = 39) or noncandidate (n = 54). The screening examination is detailed in the Diagnosis/Classification section. Twenty-eight of the 39 rehabilitation candidates attempted rehabilitation without surgery. Rehabilitation consisted of lower extremity strengthening, agility skill training, and sport-specific skill training. Subjects returned to full activity on average 4 weeks following the screening exam. Seventy-nine percent of the rehabilitation candidates who chose nonoperative care were able to return to their previous level of activity without experiencing an episode of their knee giving-way.

In a 10-year prospective study published by Hurd et al,[63] 345 patients with acute unilateral ACL injuries were screened as described by Fitzgerald et al.[39] Fifty-eight percent of the patients were classified as noncopers (individuals who failed the screening process and who were assumed to not be good rehabilitation candidates for return to activities through nonoperative management[113]) and 42% were classified as potential copers (individuals who passed the screening process and who were believed to have the potential to return to preinjury activity level for a limited period without ACL reconstruction[113]). Seventy-two percent of patients who were classified as potential copers and received specialized neuromuscular training successfully returned to high-level sports activities, and none sustained additional chondral or meniscal lesions. The screening exam is useful for classifying potential copers who plan to return to high-level activities in the short term.

The lack of preoperative full knee range of motion is an indicator of postoperative knee range of motion loss.[56,103,106] Patients who follow a preoperative exercise program can achieve range of motion close to full before surgery.[77]

Knee extension strength deficits have been reported between 6 months and 15 years postinjury in the involved limb of patients with ACL deficient knees who have not undergone reconstructive surgery.[69] Tsepis et al[165] examined quadriceps and hamstrings strength in amateur athletes with ACL-deficient knee who had not undergone structured rehabilitation. The subjects were divided into 3 separate groups based on length of chronicity. Strength was tested isokinetically at 60° per second. They found both muscle groups to be substantially weaker at all time periods when compared to controls, ranging from 32% to 21% weaker. The quadriceps showed greater side-to-side asymmetry, whereas, hamstrings symmetry could be achieved by 1 year after injury.

Hurd et al[64] examined 349 patients with acute, complete unilateral ACL ruptures who were classified as either noncoper or potential coper using an established screening examination. Quadriceps strength was measured during a maximum voluntary isometric contraction using a burst superimposition technique. They found 12.1% side-to-side asymmetry for potential copers and 14.6% asymmetry for noncopers.

Chmielewski et al[25] examined 100 consecutive patients with complete acute ACL ruptures. They reported that the average voluntary activation deficit for the involved side quadriceps was 7.4% and for the uninvolved side quadriceps was 7.2%.

Ageberg et al[1] performed a long-term (1, 3, and 15 years) follow-up in patients with unilateral ACL injuries. They measured peak isometric flexion and extension torque and peak isokinetic flexion and extension torque. LSI values for the various torque measurements ranged from 88.2% to 100.6% at the 1-year follow-up, 94.6% to 103.0% for the 3-year follow-up, and 96.5% to 102.2% at the 5-year follow-up.

The most recent Cochrane Collaboration Review[91] of surgical versus nonsurgical interventions for ACL ruptures in adults included 2 randomized and quasi-randomized trials. Both trials were considered poor quality. Both studies were conducted in the early 1980s. Conservative treatments and surgical interventions have changed since that time. No randomized trials have been conducted using current methods of treatments. A recent published clinical practice guideline by Arroll et al[5] concluded that ACL reconstruction has the most to offer those people with recurrent instability who must perform multidirectional activity as part of their occupation or sports. The standard of care recommended by the majority of surgeons for ACL injury is early ACL reconstruction.[32]

Recently, there have been several systematic reviews investigating the outcomes of ACL reconstruction comparing hamstring autograft with bone-patella tendon-bone (BPTB) autograft. Following either surgical technique, subjective knee function, as measured by knee outcome scores and GRS, are lowest early after surgery and improve up to 6 years postsurgery.[61,77,112] Using the Cincinnati Knee Rating System, scores improved from 60.5/100 at 12 weeks postreconstruction to 85.9/100 at 1-year follow-up.[61] Using the GRS, scores improved from 63.1/100 taken at week 12 to 83.3/100 at week 52.[61]

Moksness and Risberg[112] reported similar postsurgical GRS results of 86.0/100 at 1 year follow-up. Functional performance post-ACL reconstruction also improved over time. As measured by the single-limb single hop for distance test, LSI improved from 85% at 6 months to 91.8% to 95% at 12 months.[31,112] Using the single-limb triple crossover and 6-meter timed hop tests, LSI scores improved from 76.8% and 79.1%, respectively, at 12 weeks[61] to 91.9% to 93.5% and 94.2% to 94.7%, respectively, at 1-year follow-up.[61,112] At a 2- to 5-year follow-up, LSI improved to 99.5% for the single-limb single-hop-for-distance test and to 96.4% for the single-limb vertical jump.[2] Most postsurgical rehabilitation protocols enable individuals to return to sports-specific activities between 4 to 6 months post-ACL reconstruction with a full return to sports at 6 to 12 months.[23,100]

At a 5-year follow-up, Lee et al[88] reviewed 45 individuals following ACL reconstruction regarding their return to sport. Sixty-two percent of individuals returned to their previous level of sports and maintained their Tegner activity level of 6 out of 10. Twenty percent did not return to their previous level of activity due to fear of injury and 18% due to persistent instability and pain.

The loss of knee range of motion can have a disabling effect on an individual's gait.[110] The incidence of range of motion loss problems following ACL reconstruction has been reported to be between 2% and 11%.[110] A recent long-term study by Shelbourne and Gray[143] indicates that 73% of patients had normal knee extension and flexion, 10% had normal extension but less than normal flexion, 10% had less than normal extension but normal flexion, and 6% had less than normal knee extension and flexion following knee surgery.

Mauro et al[103] found that 25.3% of patients had a loss of knee extension 4 weeks after ACL surgery. Loss of extension was associated with preoperative knee extension range of motion, time from injury to surgery, and use of autograft.[103] Small (3° to 5°) knee extension loss adversely affects subjective and objective results following ACL reconstruction, and loss of normal extension and flexion results in lower quadriceps strength.[143]

Deficits in quadriceps strength following ACL reconstruction have been reported at various isokinetic testing speeds and years postreconstruction.[69] The largest extent of quadriceps weakness occurs in the first months after reconstruction.[31,69,77] Deficits in the uninvolved limb have also been reported several years following surgery.[69] Some evidence exists that strength deficits in the hamstrings may be more associated with the hamstring graft choice.[69]

Ageberg et al[2] investigated muscle strength in patients who had received conservative, nonsurgical treatment as compared to patients who had undergone surgical reconstruction and postsurgical rehabilitation under the guidance of a physical therapist. At 2- to 5-year follow-up, 44% of the surgically treated patients and 44% of the nonsurgically treated patients had normal limb symmetry values (>90%) for muscle power. Moisala et al[111] tested the quadriceps and hamstrings isokinetically in 16 patients with BPTB graft ACL reconstruction and 32 patients with hamstring graft ACL reconstruction between 4 to 7 years follow-up. He found that no significant strength deficits existed between patient groups. Muscle strengths were better in patients with a longer follow-up.

Posterior Cruciate Ligament Injuries A systematic review by Grassmayr et al[49] evaluated the biomechanical and biological consequences of PCL deficiency. They reviewed 47 articles published up to 2006. The majority of studies found no correlation between laxity and functional or subjective outcomes. Shelbourne and Muthukaruppan[145] reported that the mean score on the modified Noyes subjective questionnaires was 85.6/100 and there was no significant difference in modified Noyes scores based on PCL laxity grade. At follow-up greater than 5 years, the mean Tegner score was 5.7 to 6.6/10.[119,142] The majority of subjects treated nonoperatively can expect to return to activity at the same or similar level.[49] Fifty to 76% of patients with isolated PCL injuries were able to return to sports or activity at a similar level, 33% returned at a lower level, and 17% did not return to the same sport[49,142,145]; however, high-speed running may be most affected.[162] In contrast, Keller et al[78] reported that a majority were limited in activity with 90% reporting activity-dependent knee pain and almost half (43%) complaining of problems during ambulation.

No significant differences have been noted in range of motion following PCL injury with 4° of hyperextension and 141° of flexion in the PCL-injured knee and 4° of hyperextension and 140° of flexion in the uninvolved knee.[142]

Inconclusive results were found on muscle strength following PCL injury.[49] Six studies found no differences in muscle strength, while 5 studies found either eccentric or concentric weakness in the quadriceps in the PCL limb. One study found hamstring strength deficits within 6 months of the index injury. However, a number of factors may confound the results on the effect of strength, such as time after injury, the laxity grade, severity and mechanism of injury, assessment protocol, and the interventions received.

Collateral Ligament Injuries The long-term outcomes for nonoperative treatment of MCL injuries may depend upon the grade of injury. Kannus[75] showed that the long-term outcomes for isolated grade III (complete tear) sprains of the MCL were much worse than for grade I and II sprains, with a higher rate of medial instability, muscle weakness, and poor functional outcomes. However, others have shown that individuals with higher grade MCL injuries can have successful outcomes and return to sports.[68,123]

Posterolateral Corner Injuries Treatment of PLC injuries is dependent upon the severity and timing of the injury. Good results have been documented for grade I and moderate grade II injuries using nonoperative treatment. Conservative management of more severe PLC injuries leads to poor functional outcomes, indicating the need for surgical management of these injuries. Surgical intervention of acute PLC injuries has resulted in better success than operative management of chronic PLC injuries.[131]

Multiple Ligament Injuries The management of combined ACL/grade III MCL injuries is varied.[54] Individuals who undergo ACL reconstruction and nonoperative treatment of the MCL can expect good to excellent results. Greater and more rapid strength gains were seen in these patients. Higher incidences of range of motion limitations were present in patients with surgical interventions to both ligaments. Others have showed excellent functional outcomes with the vast majority of individuals returning to preinjury level of sports following MCL repair and conservative management of the ACL. Varied results were seen in the nonoperative treatment of combined ACL and MCL lesions.

Tzurbakis and colleagues[166] compared the results of surgical treatment of individuals with multiple knee ligament injuries. Forty-eight patients were classified based on specific anatomical structures injured: ACL/MCL involvement (group A), ACL or PCL ruptures combined with PLC injuries (group B), and knee dislocations (group C). Forty-four patients were followed up at a mean of 51.3 months. No differences were noted between groups in Lysholm scores. Tegner scores at follow-up compared to the initial evaluation were lower in groups B and C, with no difference in group A. Seventy-seven percent of the patients considered their knee to be normal or nearly normal. No differences were noted in range of motion, loss of extension, and loss of flexion among groups.

RISK FACTORS

Anterior Cruciate Ligament There are multiple risk factors associated with noncontact ACL injuries. The risk factors can be divided into 4 categories: environmental, anatomical, hormonal, and neuromuscular.

II Evidence regarding environmental risk factors suggests that increasing the shoe-surface interaction for higher traction may increase the risk of injury to the ACL.[50,51] The evidence on preventive knee brace use is inconsistent and equivocal.[50,51]

II There is evidence regarding anatomical factors, in a select, athletic, college-aged population, that a combination of increased body mass index, narrow femoral notch width, and increased joint laxity (defined by KT-2000 arthrometer or hyperlaxity measures), is directly associated and predictive of ACL injury (relative risk, 21.3).[51,167] Anatomical risk factors may be more difficult to modify than other risk factors.

II In regards to hormonal risk factors, evidence supports that most ACL injuries in female athletes occur during the early and late follicular phases of the menstrual cycle. In a systematic review by Hewett et al,[60] which included studies published through 2005, the authors concluded that female athletes may be more predisposed to ACL injuries during the preovulatory phase of the menstrual cycle. Hormonal intervention for ACL injury prevention is not warranted, and evidence is lacking for activity modification or sports participation restriction for women at any time during their menstrual cycles.

II Significant knowledge in ACL risk factors stems from the clarification of risk factors attributed to neuromuscular components. Current research suggests that a combined loading pattern is most detrimental with respect to ACL injury. Movement patterns that appear to increase ACL injury risk include a valgus or varus and extension moments, especially during slight knee flexion ("dynamic" knee valgus).[51,148] Each segment of the lower extremity kinetic chain may play a role in injury of the ACL.[50] Strong quadriceps activation during eccentric contractions may be a main factor in the injury risk to the ACL.[50,148] Neuromuscular control may be important to injury risk and the most modifiable risk factor.[58]

Posterior Cruciate Ligament, Collateral, Multiligament The vast majority of PCL, collateral, and multiple ligament injuries are the result of contact injuries. Thus, a lack of evidence exists regarding risk factor stratification for these injuries.

B Clinicians should consider the shoe-surface interaction, increased body mass index, narrow femoral notch width, increased joint laxity, preovulatory phase of the menstrual cycle in females, combined loading pattern, and strong quadriceps activation during eccentric contractions as predisposing factors for the risk of sustaining a noncontact anterior cruciate ligament (ACL) injury.

DIAGNOSIS/CLASSIFICATION

III Classification of knee stability and movement coordination impairments can be defined by passive knee stability and dynamic knee stability. However, a poor relationship exists between the amount of anterior knee joint laxity and functional abilities among patients with ACL deficient knees.[64] A small percentage of patients with ACL rupture can successfully return to sport without ACL surgery.[117] Therefore, a classification system was developed to determine which active individuals with an ACL sprain have a good probability of returning to a high level of functioning without surgical intervention in the short term, classifying these individuals as a potential coper or noncoper.[39] Assessing movement coordination impairments are a major component of this classification, which has been used to help decision making regarding rehabilitation activities for patients not receiving ACL reconstructive surgery or regarding rehabilitative activities while awaiting ACL surgery.[64]

Prescreening Criteria[39,63] Subjects who meet the following criteria are eligible to complete the screening exam:

- Level I or II athlete or worker
- No concomitant injuries
- No to trace knee effusion
- Full knee range of motion
- Normal gait
- >70% isometric quadriceps strength on bilateral comparison
- Hop up and down on the injured limb without pain

Screening Exam[35] The screening examination includes the following tests:

- Report of the number of knee giving-way episodes from the time of injury to the time of the screening
- Maximum voluntary isometric quadriceps strength testing
- Four single-limb hop tests
- Knee Outcome Survey activities of daily living scale (KOS-ADLS)
- Global rating scale of perceived knee function (GRS)

The classification system described by Fitzgerald et al[39] is based on:

- Number of giving-way episodes less than or equal to 1 episode
- Single-limb 6-m timed hop test for the involved limb greater than or equal to 80% as compared to the uninvolved limb
- KOS-ADLS greater than or equal to 80%
- GRS greater than or equal to 60%

Individuals must meet all the above criteria to be classified as a potential coper. If an individual does not pass any one criterion, he/she is classified as a potential noncoper.

Following nonoperative rehabilitation, a vast majority of potential copers were able to return to high-level activity for a short-time period (ie, to finish the sports season) without episodes of giving-way or extending their knee injury.[39,40] Seventy-two to 79% of patients who were classified as potential copers and underwent specialized neuromuscular training (perturbation training) were able to successfully return to all preinjury activities at the preinjury level for a limited period.[39,63] However, Moksnes et al[113] found a low negative predictive value for the early classification scheme at 1-year follow-up that suggests that potential noncopers should also be considered candidates for nonoperative rehabilitation.

I Moksnes et al[113] investigated the predictive value at 1-year follow-up of the screening examination proposed by Fitzgerald et al[39] on subjects who underwent nonoperative ACL treatment. One hundred twenty-five consecutive subjects were screened as either potential noncopers (n = 79) or potential copers (n = 46) with 102 subjects available for 1-year follow-up. Potential noncopers and potential copers were classified according to the screening criteria defined by Fitzgerald et al.[39] Subjects were considered true copers if they had resumed their previous level of activity without giving-way episodes at 1-year follow-up and true noncopers if they had not returned to their previous activity level or had experienced episodes of giving-way at 1-year follow-up. The sensitivity of the screening examination was 44.1% for correctly identifying true copers at 1-year follow-up, specificity was 44.4% for correctly identifying true noncopers at 1-year follow-up, positive predictive value for correctly classifying true copers at the screening examination was 60%, and negative predictive value for correctly classifying true noncopers at the screening exam was 29.8%. The screening examination has poor predictive value for classifying individuals with ACL injury at 1-year follow-up. Potential copers and potential noncopers can be equally considered candidates for nonoperative ACL management.

I The ICD diagnosis of a sprain of the anterior cruciate ligament and the associated ICF diagnosis of knee stability and movement coordination impairments is made with a reasonable level of certainty when the patient presents with the following clinical findings[12,64,73,94,138]:

- Mechanism of injury consisting of deceleration and acceleration motions with noncontact valgus load at or near full knee extension
- Hearing or feeling a "pop" at time of injury
- Hemarthrosis within 0 to 2 hours following injury
- History of giving way
- Loss of end range knee extension
- Positive Lachman test with nondiscrete end feel or increased anterior tibial translation
- Positive pivot shift test with nearly normal ("glide"), abnormal ("clunk"), or severely abnormal ("gross") shift at 10° to 20° of knee flexion
- 6-m single-limb timed hop test result that is less than 80% of the uninvolved limb
- Maximum voluntary isometric quadriceps strength index that is less than 80% using burst superimposition technique.

I The ICD diagnosis of a sprain of the posterior cruciate ligament and the associated ICF diagnosis of knee stability and movement coordination impairments is made with a reasonable level of certainty when the patient presents with the following clinical findings[73,74,97,152]:

- Posterior directed force on the proximal tibia (dashboard/anterior tibial blow injury), a fall on the flexed knee with the foot in plantar flexion or a sudden violent hyperextension of the knee joint
- Abrasions or ecchymosis on the anterior aspect of the proximal tibia
- Localized posterior knee pain with kneeling or decelerating
- Positive posterior drawer test at 90° with a nondiscrete end feel or an increased posterior tibial translation
- Posterior sag test with a subluxation or 'sag' of the proximal tibia posteriorly relative to the anterior aspect of the femoral condyles
- A positive modified stroke test or Bulge sign
- Loss of knee extension during gait observation or range of motion testing

I The ICD diagnosis of a sprain of the medial (tibial) collateral ligament and the associated ICF diagnosis of knee stability and movement coordination impairments is made with a reasonable level of certainty when the patient presents with the following clinical findings[76,123,130]:

- Trauma by a force applied to the lateral aspect of the lower extremity
- Rotational trauma
- Pain with valgus stress test performed at 30° of knee flexion
- Increased separation between femur and tibia (laxity) with a valgus stress test performed at 30° of knee flexion
- Normal knee range of motion
- Palpatory provocation of MCL reproduces familiar pain
- A positive modified stroke test or Bulge sign

IV The ICD diagnosis of a sprain of the lateral (fibular) collateral ligament and the associated ICF diagnosis of knee stability and movement coordination impairments is made with a reasonable level of certainty when the patient presents with the following clinical findings[21]:

- Excessive varus trauma
- Localized effusion over the LCL
- Palpatory provocation of LCL reproduces familiar pain
- Pain with varus stress test performed at 0° and 30° of knee flexion
- Increased separation between femur and tibia (laxity) with varus stress test applied at 0° and 30° of knee flexion
- A positive modified stroke test or Bulge sign

A Passive knee instability, joint pain, joint effusion, and movement coordination impairments are useful clinical findings for classifying a patient with knee instability into the following International Statistical Classification of Diseases and Related Health Problems (ICD) categories: Sprain and strain involving collateral ligament of knee, sprain and strain involving cruciate ligament of knee, injury to multiple structures of knee; and the associated International Classification of Functioning, Disability, and Health (ICF) impairment-based category of knee instability (**b7150 Stability of a single joint**) and movement coordination impairments (**b7601 Control of complex voluntary movements**).

DIFFERENTIAL DIAGNOSIS

A PRIMARY GOAL OF DIAGNOSIS IS TO MATCH THE PATIENT'S clinical presentation with the most efficacious treatment approach.[24] One component is to determine the appropriateness of physical therapy management.[24] However, in a small percentage of patients, trauma to the knee may be something more severe, such as fracture,[7] knee dislocation,[134] or neurovascular compromise.[134] Following surgical intervention, serious conditions may develop, such as arthrofibrosis,[103,104] postoperative infection and septic arthritis,[168] deep vein thrombosis,[127] anterior knee pain,[45,66] and patella fractures.[159] Vigilance is warranted of the major signs and symptoms associated with serious knee conditions, continually screening for the presence of these conditions, and initiate referral to the appropriate medical practitioner when a potentially serious medical condition is suspected.[24]

III Psychosocial factors may partially contribute to an inability to return to preinjury activity levels. Fear of movement/reinjury decreases as a patient is further removed from surgery and is inversely related to knee performance as a function of time.[26] Patients that did not return to their preinjury activity level had more fear of reinjury, which was correlated with low knee-related quality of life.[84] Elevated pain-related fear of movement/reinjury based on a shortened version of the Tampa Scale for Kinesiophobia (TSK-11) place a patient at risk for chronic disability and reducing this fear can be accomplished through patient education and graded exercise prescription.[26,89] Thomee et al[161] found that patients' perceived self-efficacy of knee function using the knee self-efficacy scale (K-SES) prior to ACL reconstruction is predictive of return to acceptable levels of physical activity, symptoms, and muscle function 1 year following ACL reconstruction.

B Clinicians should consider diagnostic classifications associated with serious pathological conditions or psychosocial factors when the patient's reported activity limitations or impairments of body function and structure are not consistent with those presented in the diagnosis/classification section of this guideline or when the patient's symptoms are not resolving with interventions aimed at normalization of the patient's impairments of body function.

IMAGING STUDIES

Acute knee injury is one of the most common orthopaedic conditions. When a patient reports a history of knee trauma, the therapist needs to be alert for the presence of fracture. Being able to properly identify when to obtain radiographs of the knee can eliminate needless radiographs and be cost-effective.[7] The Ottawa Knee rule has been developed and validated to assist clinicians in determining when to order radiographs in individuals with acute knee injury.[7,154] A knee radiograph series are required in patients with any of the following criteria:

- Age 55 or older
- Isolated tenderness of patella (no bone tenderness of knee other than patella)
- Tenderness of head of the fibula
- Inability to flex knee to 90°
- Inability to bear weight both immediately and in the emergency department for 4 steps regardless of limping

Clinical examination by well-trained clinicians appears to be as accurate as magnetic resonance imaging (MRI) in regards to the diagnosis of cruciate, collateral, or anatomic quadrants lesions of the knee.[11,80,94] MRI may be reserved for more complicated or confusing cases.[80] MRI may assist an orthopaedic surgeon in preoperative planning and predicting the prognosis.[80,94]

CLINICAL GUIDELINES

Examination

OUTCOME MEASURES

A vast number of knee injury outcomes scales have been developed and used over the years to evaluate a patient's disability. Recently, 2 reviews have been completed on knee outcome scales.[92,172]

I

The Medical Outcomes Study 36-item Short Form (SF-36) is currently the most popular general health outcome measure.[172] The measure was designed to improve on the ability to measure general health outcomes without significantly lengthening the questionnaire and could be completed in less than 10 minutes. The SF-36 consists of 35 questions in 8 subscale domains and 1 general overall health status question. Each subscale score is totaled, weighted, and transformed to fall between 0 (worst possible health, severe disability) and 100 (best possible health, no disability).[118] The SF-36 form has been validated for a variety of ages and languages.[172] It has demonstrated effectiveness in a vast number of conditions pertaining to orthopaedic and sports injuries.

III

Shapiro et al[141] investigated the use of the SF-36 to determine if this assessment tool could identify patients who required ACL reconstruction, could detect changes with treatment over time, and was correlated with the IKDC knee evaluation form, Lysholm scoring scale, and the Tegner activity scale at baseline and at the 3 follow-up periods. The 3 SF-36 scales related to musculoskeletal injury were analyzed: physical function, role physical, and bodily pain. One hundred sixty-three patients with ACL injuries were given the questionnaires. Follow-up evaluation occurred at 6 months and at 1 and 2 years. Subject groups consisted of patients recommended for ACL surgery with surgery performed, those recommended for surgery without surgery performed, those not recommended for surgery and treated nonoperatively, and those not recommended for surgery initially but who underwent surgery later for chronic symptoms. The SF-36 was able to discriminate between acute (<4 months postinjury) and chronic (>4 months postinjury) ACL injuries at the baseline evaluation. Although, no correlations were found at any time period in any treatment group, the authors found changes greater than 10 points in many of the physical health-based scales, indicating that this difference may be meaningful and may be significant with a larger sample size. The scores on the SF-36 and Lysholm scale were moderately correlated in the acute and chronic groups, the scores between the SF-36 physical functioning subscale and Tegner scale were minimally correlated in only the chronic ACL group, and the scores between the SF-36 and IKDC score were weakly correlated in both groups. The authors concluded that the SF-36 can discriminate between injury classification stages at baseline and can detect changes with treatment over time.

I

The Knee Outcome Survey-Activities of Daily Living Scale (KOS-ADLS) is a patient-reported measure of functional limitations and impairments of the knee during activities of daily living.[71] The KOS-ADLS contains 7 items related to symptoms and 10 related to functional disability during activities of daily living. Each item is scored 0-5 and the total score is expressed as a percentage, with lower scores corresponding to greater disability. Irrgang et al[71] identified a higher internal consistency of the KOS-ADLS than that of the Lysholm Knee Scale. They also identified that validity of the scale was demonstrated by a moderate correlation with the Lysholm Knee Scale and the global assessment of function. They found that the KOS-ADLS is responsive for the assessment of functional limitations of the knee. The test-retest intraclass correlation coefficient ($ICC_{2,1}$) was 0.97, standard error of measurement (SEM) was 3.2, and minimum detectable change at 95% confidence level (MDC_{95}) was 8.87.

I

The Knee Injury and Osteoarthritis Outcome Score (KOOS) is designed as a patient-reported assessment for evaluating sports injuries and outcomes in the young and middle-aged athlete.[135,172] The KOOS consists of items in 5 domains, 9 items related to pain, 7 items related to symptoms, 17 items related to activities of daily living, 5 items related to sport and recreation function, and 4 items related to knee-related quality of life. Each item is graded from 0 to 4. Each subscale is summed and transformed to a score of 0 (worst) to 100 (best). Roos and colleagues[135,172] identified a moderate relationship with the physical function domains of the KOOS and the SF-36 physical health domains but weak correlations with the KOOS domains and the SF-36 mental health domains. MDC_{95} for pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life domains are 13.85, 9.97, 11.92, 22.96, and 15.45, respectively. The pain, sport and recreation, and quality of life domains have been determined to be the most responsive to change, with the largest effect size for active, young patients.[172] The KOOS has been demonstrated to contain items regarding symptoms and disabilities important to patients with an ACL tear, isolated meniscal tears, or knee osteoarthritis.[158]

I The International Knee Documentation Committee 2000 Subjective Knee Evaluation Form (IKDC 2000) is a joint-specific outcome measure for assessing symptoms, function, and sports activity pertinent to a variety of knee conditions.[172] The form contains 18 questions, in which the total scores are expressed as a percentage. The IKDC has been demonstrated to contain items regarding symptoms and disabilities important to patients with an ACL tear, isolated meniscal tears, or knee osteoarthritis.[158]

Irrgang et al[70] were able to demonstrate the responsiveness of the IKDC 2000 Subjective Knee Form. Two hundred and seven patients with a variety of knee pathologies who had scores at baseline and final follow-up participated in this study. They were able to identify a change score of 11.5 had a sensitivity of 0.82 and a specificity of 0.64, indicating that a person who scored less than 11.5 perceived himself as not improved, whereas, a change score of 20.5 had a sensitivity of 0.64 and a specificity of 0.84, indicating that a person who scored greater than 20.5 perceived himself as improved. MDC for the IKDC was a score of 12.8 for knee disorders. Based on the close agreement of the cutoff score and MDC, a score of 11.5 is necessary to distinguish between those who have improved and those who have not improved.

II The Lysholm Knee Scale was originally designed for follow-up evaluation of knee ligament surgery.[172] The scale contains 8 items of symptoms and function. It is scored from 0 to 100 points. Instability and pain are weighted the most heavily.[172] The Lysholm scale is arbitrarily graded with 95 to 100 as excellent, 84 to 94 as good, 65 to 83 as fair, and $<$65 as poor. Research to date on validity, sensitivity, and reliability of the Lysholm scale is inconclusive.[172] The Lysholm scale may prove to be more meaningful when combined with an activity rating scale.[140] Two studies have examined the test retest reliability of the Lysholm Knee Scale.[20,81] These have demonstrated the overall ICC for test retest reliability of 0.70 to 0.93.

II The Cincinnati Knee Rating Scale is a clinician-based and patient-reported outcome measure. It was developed to assess subjective symptoms and functional activities.[172] It has been modified over the years. It has been designed as a 6 dimension scale based on a total of 100 points: symptoms (20 points), daily and sports activities (15 points), physical examination (25 points), knee stability testing (20 points), radiographic findings (10 points), and functional testing (10 points).[10] Portions of the rating scale have been validated.[172] The ICC value for test retest reliability in patients with ACL reconstruction was greater than 0.75.[10] The MDC_{95} for pain, swelling, partial giving-way, and full giving-way factors was 2.45, 2.86, 2.82, and 2.30, respectively. The effect size for responsiveness for change for pain, swelling, partial giving-way, full giving-way, symptoms average, ACL function average, sports function average, and overall rating score was 1.40, 1.18, 1.87, 1.49, 1.74, 0.69, 1.91, and 3.49, respectively (effect size greater than 0.80 is considered large effect).

V The Tegner Activity Level Scale was developed as a score of activity level from 0 to 10 points. The scale grades a person's activity level where 0 is "on sick leave/disability" and 10 is "participation in competitive sports at the national elite level." It is commonly used in combination with the Lysholm score.[172]

II The Marx Activity Level Scale is a patient-reported activity assessment. It contains 4 questions evaluating high-level functional activities. Each question is scored 0-4, based on the frequency per week each item is performed. It is designed to assess the patient's highest peak activity over the past year.[172] The scale has been validated[101] but responsiveness has not been determined.[172]

B Clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee stability and movement coordination impairments. These tools are useful for identifying a patient's baseline status relative to pain, function, and disability and for monitoring changes in the patient's status throughout the course of treatment.

ACTIVITY LIMITATION AND PARTICIPATION RESTRICTION MEASURES

A variety of activity limitation and participation restriction measures have been described in the literature. The most common method used to quantify lower extremity function is through functional performance tests. Hop testing has frequently been proposed as a practical, performance-based outcome measure that reflects the integrated effect of neuromuscular control, strength, and confidence in the limb.[129] Hop testing can be performed in patients with ACL-deficient knee if they meet the prescreening criteria.[39] In patients following ACL reconstruction, hop testing can be performed at 12 weeks if they meet the prescreening criteria with the exception of greater than or equal to 80% isometric quadriceps strength on bilateral comparison.[99]

The single-limb hop tests are the most common hop tests utilized to capture limb asymmetries in patients with lower extremity dysfunction. The following 4 hop tests are primarily used in patients with knee lesions: single-limb single hop for distance, single-limb triple crossover hop for distance, single-limb triple hop for distance, and single-limb 6-m timed hop.

These hop tests have demonstrated high test retest reliability in normal, young adults.[18,136] ICCs for single-limb single hop for distance ranged from 0.92 to 0.96, single-limb triple crossover hop for distance ranged from 0.93 to 0.96, single-limb triple hop for distance ranged from 0.95 to 0.97, and single-limb 6-m timed hop ranged from 0.66 to 0.92.

III Noyes and colleagues[115] regard a LSI of less than 85% as abnormal. Following ACL rupture, 50% of the patients exhibited abnormal LSI on a single-limb hop test. If the results of 2 hop tests were calculated, 62% of the patients were identified as having abnormal scores.

III Following ACL reconstruction, patients performed hop tests at 16 weeks postoperatively (day 1), 16 weeks plus 24 to 48 hours (day 2 and 3), and 22 weeks postoperatively (day 4).[129] Hop test LSI test retest reliability was assessed using values from day 2 and 3. ICCs ranged from 0.82 to 0.88 with overall combination of hop tests being 0.93.

III Low to moderate correlations were found between hop test performance and lower extremity muscular strength, as well as, between hop test performance and self-report outcome measures.[41]

Other activity limitation and participation restriction measures may be a part of the patient-reported outcome measure noted in this guideline's section on Outcome Measures. No literature exists regarding functional performance tests for patients with PCL, collateral, and multiligament injuries.

C Clinicians should utilize easily reproducible physical performance measures, such as single-limb hop tests, to assess activity limitation and participation restrictions associated with their patient's knee stability and movement coordination impairments, to assess the changes in the patient's level of function over the episode of care, and to classify and screen knee stability and movement coordination.

ACTIVITY LIMITATION AND PARTICIPATION RESTRICTION MEASURES

Single-limb Single Hop Test for Distance

ICF category	Measurement of activity limitation, jumping
Description	The distance a patient travels when a single hop on 1 limb is performed.
Measurement method	The patient stands on the uninvolved limb, with toes on the starting line. The patient hops as far as possible forward and lands on the same limb. The distance hopped is measured from the starting line to the point where the patient's heel landed. The patient is given 2 practice trials and 2 recorded trials. Testing is repeated on the involved limb. Wearing a functional knee brace is recommended for all patients postinjury or less than 1 year postsurgery.
Nature of variable	Continuous
Units of measurement	Centimeters
Measurement properties	Test-retest reliability • Healthy individuals: $ICC_{2,3}$ = 0.92, SEM = 4.61 cm, MDC_{95} = 12.78 cm[136] • Mean distance: 208.08-208.24 cm LSI reliability in patients with ACL reconstruction[129] • $ICC_{2,1}$ = 0.92 • MDC_{90} = 8.09% • Range of mean LSI at 16 weeks post-ACL reconstruction = 81.0%-82.9% • Mean LSI at 22 weeks post-ACL reconstruction = 88.2%

Single-Limb Triple Hop Test for Distance

ICF category	Measurement of activity limitation, jumping
Description	The distance a patient travels when 3 maximal forward hops are performed in succession.
Measurement method	The patient stands on the uninvolved limb, with the toes on the starting line. The patient performs 3 consecutive maximal hops as far as possible forward and lands on the same limb. The distance hopped is measured from the starting line to the point where the patient's heel landed after the third hop. The patient is given 2 practice trials and 2 recorded trials. The test is repeated on the involved limb. Wearing a functional knee brace is recommended for all patients postinjury or less than 1 year postsurgery.

Single-Limb Triple Hop Test for Distance (continued)

Nature of variable	Continuous
Units of measurement	Centimeters
Measurement properties	Test-retest reliability • Healthy individuals: $ICC_{2,3}$ = 0.97, SEM = 11.17 cm, MDC_{95} = 30.96 cm[136] • Mean distance: 670.12-673.35 cm LSI reliability in patients with ACL reconstruction[129] • $ICC_{2,1}$ = 0.88 • MDC_{90} = 10.02% • Range of mean LSI at 16 weeks post-ACL reconstruction = 82.1%-82.6% • Mean LSI at 22 weeks post-ACL reconstruction = 87.7%

Single-Limb Crossover Hop Test for Distance

ICF category	Measurement of activity limitation, jumping
Description	The distance a patient travels when 3 maximal crossover forward hops are performed.
Measurement method	The patient stands on the uninvolved limb, with the toes on the starting line. The patient performs 3 consecutive maximal hops as far as possible forward and lands on the same limb while alternately crossing over a 15-cm strip on the floor. The distance hopped is measured from the starting line to the point where the patient's heel landed after the third hop. The patient is given 2 practice trials and 2 recorded trials. The test is repeated on the involved limb. Wearing a functional knee brace is recommended for all patients postinjury or less than 1 year postsurgery.
Nature of variable	Continuous
Units of measurement	Centimeters
Measurement properties	Test-retest reliability • Healthy individuals: $ICC_{2,3}$ = 0.93, SEM = 17.74 cm, MDC_{95} = 49.17 cm[136] • Mean distance: 637.40-649.19 cm LSI reliability in patients with ACL reconstruction[129] • $ICC_{2,1}$ = 0.84 • MDC_{90} = 12.25% • Range of mean LSI at 16 weeks post-ACL reconstruction = 82.2%-84.4% • Mean LSI at 22 weeks post-ACL reconstruction = 88.3%

Single-Limb 6 Meter Hop Test for Time

ICF category	Measurement of activity limitation, jumping
Description	The amount of time a patient needs to hop on 1 limb a distance of 6-m as quickly as possible.
Measurement method	The patient stands on the uninvolved limb, with the toes on the starting line. After the examiner's command of "Ready, set, go," timing begins with a stopwatch accurate to 0.01 seconds. The patient hops the 6-m distance as quickly as possible with the test limb. The testing stops when the subject crosses the 6-m finish line. The patient performs 2 practice hops and performs 2 recordable hops. Testing is repeated on the involved limb. Wearing a functional knee brace is recommended for all patients postinjury or less than 1 year postsurgery.
Nature of variable	Continuous
Units of measurement	Seconds
Measurement properties	Test-retest reliability • Healthy individuals: $ICC_{2,3}$ = 0.93, SEM = 0.06 s, MDC_{95} = 0.17 s[136] • Mean time: 1.82-1.86 s LSI reliability in patients with ACL reconstruction[129] • $ICC_{2,1}$ = 0.82 • MDC_{90} = 12.96% • Range of mean LSI at 16 weeks post-ACL reconstruction = 81.7%-83.2% • Mean LSI at 22 weeks post-ACL reconstruction = 89.6%

PHYSICAL IMPAIRMENT MEASURES

Modified Stroke Test

ICF category	Measurement of impairment of body structure, knee joint
Description	The amount of fluid in the knee joint measured by visual inspection by clinician
Measurement method	A stroke test is performed with the patient in supine and with the knee in full extension and relaxed. Starting at the medial joint line the examiner strokes upward 2 or 3 times toward the suprapatellar pouch in an attempt to move effusion from the knee. The examiner then strokes downward on the distal lateral thigh just superior to the suprapatellar pouch toward the lateral joint line. A wave of fluid may be observed within seconds on the medial side of the knee.[6,95,155]
Nature of variable	Ordinal
Units of measurement	Grading: Zero = no wave produced with downward stroke Trace = small wave of fluid on the medial side of the knee 1+ = Larger bulge of fluid on the medial side of the knee 2+ = Effusion completely fills the medial knee sulcus with downward stroke or returns to the medial side of the knee without downward stroke 3+ = Inability to move the effusion out of the medial aspect of the knee
Measurement properties	The modified stroke test has a Kappa value of 0.61.[155] 72% of testing pairs had perfect agreement. 8% had a disagreement of 2 grades.
Instrument variations	Other effusion tests can be used to assess knee effusion.[27,76] In addition to visual inspection, knee effusion can be measured using a tape measure or perometer (an optoelectric device designed to measure limb volume) for knee circumference.[98,160]

Bulge Sign

ICF category	Measurement of impairment of body structure, knee joint
Description	The amount of fluid in the knee joint measured by visual inspection by clinician
Measurement method	The examiner, with 1 hand located superior to the patella, pushes the tissues (and possible fluid) inferiorly towards the patella. Keeping this hand in this position while holding pressure on these tissues, the examiner uses their other hand to press the medial aspect of the knee just posterior to the patellar edge to force any fluid within the joint laterally. While watching the medial joint area, the hand over this area is taken and used to press quickly along the lateral (ie, opposite) aspect of the knee, looking for a fluid wave to present medially.
Nature of variable	Nominal
Units of measurement	• Absent • Present
Measurement properties	Reliability coefficient of 0.97[27] in patients with knee osteoarthritis.
Instrument variations	Other effusion test can be used to assess knee effusion.[76] In addition to visual inspection, knee effusion can be measured using a tape measure or perometer for knee circumference.[98,160]

Knee Passive Range of Motion

ICF category	Measure of impairment of body function, mobility of a single joint
Description	The amount of passive knee extension and flexion measured using a goniometer
Measurement method	For measurement using the goniometer, 1 arm of the goniometer is placed parallel to the shaft of the femur lining up with the greater trochanter, and the other arm is placed parallel to the shaft of the lower leg lining up with the lateral malleolus of the fibula. The axis of the goniometer is placed over the lateral femoral epicondyle. **Knee extension:** The patient is supine. The heel of the limb of interest is propped on a bolster, assuring the back of the knee and calf are not touching the support surface. The amount of knee extension is recorded with the goniometer. **Knee flexion:** The patient is supine. The patient flexes the knee as far as possible. The therapist then passively flexes the knee to the point of tissue resistance. The amount of knee flexion is recorded with the goniometer.

Knee Passive Range of Motion (continued)

Nature of variable	Continuous
Units of measurement	Degrees
Measurement properties[124]	• Validity: ICC = 0.98-0.99 • Intraexaminer reliability coefficients ranging from ICC = 0.85-0.99 • Interexaminer reliability coefficients ranging from ICC = 0.62 to 0.99 • SEM = 2.37°, MDC_{95} = 6.57°

Knee Active Range of Motion

ICF category	Measure of impairment of body function, mobility of a single joint
Description	The amount of active knee extension and flexion measured using a goniometer
Measurement method	For measurement using the goniometer, 1 arm of the goniometer is placed parallel to the shaft of the femur lining up with the greater trochanter, and the other arm is placed parallel to the shaft of the lower leg lining up with the lateral malleolus of the fibula. The axis of the goniometer is placed over the lateral femoral epicondyle. **Knee extension:** The patient is supine. The heel of the limb of interest is propped on a bolster, assuring the back of the knee and calf are not touching the support surface. The patient is asked to actively contract the quadriceps. The amount of knee extension is recorded with the goniometer. **Knee flexion:** The patient is prone. The patient flexes the knee as far as possible. The amount of knee flexion is recorded with the goniometer.
Nature of variable	Continuous
Units of measurement	Degrees
Measurement properties	Intraexaminer $ICC_{2,1}$ for active extension and flexion were 0.85 and 0.95, respectively[28]

Lachman Test

ICF category	Measure of impairment of body function, stability of a single joint
Description	The amount of anterior tibial translation in respect to the femur
Measurement method[12]	The Lachman test is performed with the patient lying supine and with the involved extremity on the side of the examiner. The femur is stabilized with 1 hand, with the patient's knee joint in 20 to 30° of flexion. The examiner's other hand is applied to the posterior aspect of the proximal tibia. An anteriorly directed force is applied to displace the tibia. Increased anterior tibial translation with a soft end point compared to the contralateral side constitutes a positive test, indicating disruption of the ACL.
Nature of variable	Ordinal
Units of measurement	As described by the IKDC 2000 knee examination form,[4] severity is graded as a difference in the involved knee compared to normal or what is assumed to be normal: • Normal (-1 to 2 mm) • Nearly normal (3 to 5 mm) • Abnormal (6 to 10 mm) • Severely abnormal (greater than 10 mm)
Measurement properties	Diagnostic Accuracy[12]

Diagnostic Accuracy[12]		95% Confidence Interval (CI)
Sensitivity	85%	83%-87%
Specificity	94%	92%-95%
Negative likelihood ratio	0.2	0.1-0.3
Positive likelihood ratio	10.2	4.6-22.7
Diagnostic odds ratio	70	23-206

(continued)

Lachman Test (continued)

Measurement properties *(continued)*	Reliability for Lachman test[30] • Intraexaminer judgments of positive or negative findings - κ = 0.51(range: 0.38-0.60) with 76% agreement for physical therapist and orthopaedic surgeons • Intraexaminer judgments for grading based on excursion - Weighted κ = 0.46 with 61% agreement • Interexaminer judgments of positive or negative findings - κ = 0.19-0.42 with 60-71% agreement for physical therapists
Instrument variations	The anterior tibial translation can be measured with the KT-1000 (portable arthrometer) and rolimeter (portable arthrometer)[126]

Pivot Shift Test

ICF category	Measure of impairment of body function, stability of a single joint
Description	The amount of anterior tibial translation in respect to the femur
Measurement method[12]	The pivot shift test is performed with the patient in supine. The involved limb is in an extended position. The limb is picked up at the ankle with the examiner's ipsilateral hand. This hand internally rotates the knee and flexes the knee from full extension, while applying a valgus stress with the contralateral hand on the lateral aspect of the proximal tibia. As the knee is moved into flexion, a sudden reduction of the anteriorly subluxed lateral tibial plateau indicates a positive shift test, suggesting a disruption to the ACL. This sudden reduction occurs at about 20° of knee flexion.
Nature of variable	Ordinal
Units of measurement	As described by the IKDC 2000 knee examination form,[4] severity is graded as a difference in the involved knee compared to normal or what is assumed to be normal: • Normal (equal, none) • Nearly normal (glide, +) • Abnormal (clunk, ++) • Severely abnormal (gross, +++)
Measurement properties	Diagnostic Accuracy[12]

		95% CI
Sensitivity	24%	21-27%
Specificity	98%	96-99%
Negative likelihood ratio	0.9	0.8-1.0
Positive likelihood ratio	8.5	4.7-15.5
Diagnostic odds ratio	12	5-31

Maximum Voluntary Isometric Quadriceps Strength

ICF category	Measure of impairment of body function, power of isolated muscles and muscle groups
Description	The amount of quadriceps strength and activation of the involved limb relative to the noninvolved limb
Measurement method[25,64]	The patient is seated on a dynamometer with hips and knees in 90° of flexion. The distal tibia is secured to the dynamometer force arm just proximal to the lateral malleolus, and Velcro straps are used to stabilize the thigh and pelvis. The axis of rotation is adjusted so as to align with the lateral epicondyle of the femur. After cleansing the area with alcohol, 7.6 cm by 12.7 cm self-adhesive electrodes, used to deliver the electrical stimulus during testing, are placed over the proximal vastus lateralis and the distal vastus medialis muscle bellies. To ensure that the patient is exerting a maximal effort, the patient is familiarized with the procedure, and receives verbal encouragement from the tester and visual feedback from the dynamometer's real time force display. The patient performs 3 practice trials, and testing is initiated after 5 minutes of rest. For the test, the patient is instructed to maximally contract their quadriceps for 5 seconds during which a supramaximal burst of electrical stimulation (amplitude, 135 volts; pulse duration, 600 microseconds; pulse interval, 10 milliseconds; train duration, 100 milliseconds) is applied to the quadriceps to ensure complete muscle activation. If the force produced by the patient is less than 95% of the electrically elicited force, the test is repeated, with a maximum of 3 trials per limb. To avoid the influence of fatigue, the patient is given 2-3 minutes of rest between trials. If full activation is not achieved (voluntary *(continued)*

Maximum Voluntary Isometric Quadriceps Strength (continued)

Measurement method[25,64] *(continued)*	torque less than 95% of the electrically elicited force) during any of the trials, the highest voluntary force output from the 3 trials is used for analysis. Custom software is used to identify the maximum voluntary force produced by both the uninvolved and involved limbs during testing. A quadriceps index is calculated as a strength test score after testing is completed by calculating (involved side maximum force/uninvolved side maximum force) × 100%.
Nature of variable	Continuous
Units of measurement	Force: Newtons Torque: Newton-meter Quadriceps index: percentage
Measurement properties[25]	Interrater reliability $ICC_{2,1}$: 0.97-0.98

Isokinetic Muscle Strength

ICF category	Measure of impairment of body function, power of isolated muscles and muscle groups
Description	The amount of quadriceps strength of the involved limb relative to the noninvolved limb
Measurement method[102]	The patient is seated on a dynamometer with hips positioned in 90° of flexion. The distal tibia is secured to the dynamometer force arm just proximal to the lateral malleolus, and Velcro straps are used to stabilize the thigh and pelvis. The axis of rotation is adjusted so as to align with the lateral epicondyle of the femur. To ensure that the patient is exerting a maximal effort, he is familiarized with the procedure and receives verbal encouragement from the tester and visual feedback from the dynamometer's real time force display. The patient performs 3 practice trials, and testing is initiated after 5 minutes of rest. For the test, the patient is instructed to perform 3 to 5 repetitions of maximal concentric and eccentric contractions for extension and flexion of each knee at 60°/s or 120°/s and 25 to 30 repetitions of maximal concentric and eccentric contractions for extension and flexion of each knee at 180°/s or 240°/s. Custom software is used to identify the maximum voluntary force produced by both the uninvolved and involved limbs during testing. Peak torque and total work can be determined. A quadriceps index can be calculated as a strength test score after testing is completed by calculating (involved side maximum force/uninvolved side maximum force) × 100%.
Nature of variable	Continuous
Units of measurement	Torque: Newton-meter Work: Joules Quadriceps index: Percentage
Measurement properties[151]	Test-retest reliability ICCs (95%CI):

	Peak Torque	Work
Concentric extension	0.93 (0.81-0.97)	0.94 (0.83-0.98)
Concentric flexion	0.93 (0.80-0.97)	0.88 (0.69-0.96)
Eccentric extension	0.93 (0.81-0.97)	0.95 (0.87-0.98)
Eccentric flexion	0.940 (.85-0.98)	0.94 (0.84-0.98)

MDC_{95}

	Peak Torque	Work
Concentric extension	22.76	18.02
Concentric flexion	15.44	22.73
Eccentric extension	33.93	21.81
Eccentric flexion	17.96	20.68

Posterior Drawer Test

ICF category	Measure of impairment of body function, stability of a single joint
Description	The position and amount of posterior tibial excursion in respect to the femur

Posterior Drawer Test (continued)

Measurement method[102]	The patient is supine with involved knee flexed to 90°. The examiner is seated on the foot of the involved limb and applies the thenar eminence of both hands on the anterior aspect of the proximal tibia. A posteriorly directed force is applied to displace the tibia. Increased posterior tibial translation with a soft end point compared to the contralateral side constitutes a positive test, indicating disruption of the PCL.
Nature of variable	Ordinal
Units of measurement	As described by Rubinstein et al,[137] PCL injury is graded as grade I (increased posterior tibial displacement but with the anterior tibia not flush with femoral condyles), grade II (posterior tibial displacement with anterior tibia flush with femoral condyles), or grade III (posterior tibial displacement in which the anterior tibia subluxated posterior to the anterior surface of the femoral condyles). As described by the IKDC 2000 knee examination form[4], severity is graded as a difference in the involved knee compared to normal or what is assumed to be normal: • Normal (0-2 mm) • Nearly normal (3-5 mm) • Abnormal (6-10 mm) • Severely abnormal (>10 mm)
Measurement properties[151]	Diagnostic Accuracy[137] Sensitivity 90% Specificity 99% Negative Likelihood ratio 0.1 Positive Likelihood ratio 90
Instrument variations	Posterior tibial translation can be measured with the KT-1000[35]

Posterior Sag Test

ICF category	Measure of impairment of body function, stability of a single joint
Description	The amount of posterior tibial translation in respect to the femur
Measurement method	The patient is supine. The examiner holds the heels of both limbs, and flexes the knees to 90° and the hips to 90°. The position of the proximal tibia of the involved limb is compared to the contralateral side. If the position of the proximal tibia of the involved limb is set more posterior or "sags" relative to the femoral condyles as compared to the opposite side, the test is positive for a posterior sag, suggesting disruption to the PCL.
Nature of variable	Nominal
Units of measurement	• Absent • Present
Measurement properties	Diagnostic Accuracy[137]

		95% CI
Sensitivity	79%	57-91%
Specificity	100%	85-100%
Negative likelihood ratio	0.21	0.09-0.5
Positive likelihood ratio (continuity correction)	34.1	2.18-533.57

Pain With Valgus Stress Test at 30°

ICF category	Measure of impairment of body function, pain in joint
Description	The amount of pain at the MCL during a valgus stress test performed with the knee at 30° of flexion
Measurement method	The patient is supine. While facing toward the feet of the patient, the examiner holds the ankle of the tested limb with the outside hand. The limb is extended over the edge of the testing table. The examiner places his inside thigh against the thigh of the tested limb. The knee is flexed to 30°. The opposite hand of the examiner is placed over the medial joint line of the tested limb. The examiner applies a valgus force by abducting the ankle and stabilizing the thigh. Pain at the MCL is suggestive of a disruption to the MCL. The amount of pain using the Numeric Pain Rating Scale (NPRS) at the MCL is recorded.[76]
Nature of variable	Ordinal

Pain With Valgus Stress Test at 30° (continued)

Units of measurement	0-10 NPRS
Measurement properties	Diagnostic Accuracy[76]

		95% CI
Sensitivity	78%	64-92%
Specificity	67%	57-76%
Negative likelihood ratio	0.3	0.2-0.6
Positive likelihood ratio	2.3	1.7-3.3

Laxity With Valgus Stress Test at 30°

ICF category	Measure of impairment of body function, stability of a single joint
Description	The amount of separation between the tibia and femur at the MCL during a valgus stress test performed with the knee in 30° of flexion
Measurement method	The patient is supine. While facing toward the feet of the patient, the examiner holds the ankle of the tested limb with the outside hand. The limb is extended over the edge of the testing table. The examiner places his inside thigh against the thigh of the tested limb. The knee is flexed to 30°. The opposite hand of the examiner is placed over the medial joint line of the tested limb. The examiner applies a valgus force by abducting the ankle and stabilizing the thigh. The amount of separation between the femur and tibia, suggestive of a disruption of the MCL, is recorded.
Nature of variable	Ordinal
Units of measurement	As described by the IKDC 2000 knee examination form[4], severity is graded as a difference in the involved knee compared to normal or what is assumed to be normal: • Normal (–1-2 mm) • Nearly normal (3-5 mm) • Abnormal (6-10 mm) • Severely abnormal (>10 mm)
Measurement properties	Diagnostic Accuracy[76]

		95% CI
Sensitivity	91%	81%-100%
Specificity	49%	39%-59%
Negative likelihood ratio	0.2	0.1-0.6
Positive likelihood ratio	1.8	1.4-2.2

Varus Stress Test at 0° and 30°

ICF category	Measure of impairment of body function, stability of a single joint
Description	The amount of separation between the tibia and femur at the LCL during a varus stress test performed at 0° and 30° of knee flexion
Measurement method	The patient is supine. While facing toward the feet of the patient, the examiner holds the ankle of the tested limb with the outside hand. The limb is extended over the edge of the testing table. The examiner stands between the tested limb and the examination table. The examiner places his outside thigh against the thigh of the tested limb. The knee is extended to 0°. The opposite hand of the examiner is placed over the lateral joint line of the tested limb. The examiner applies a varus force by adducting the ankle and stabilizing the thigh. The amount of separation between the femur and tibia, suggestive of a disruption of the LCL, is recorded. The test is repeated with the knee flexed to 30°.
Nature of variable	Ordinal
Units of measurement	As described by the IKDC 2000 knee examination form,[4] severity is graded as a difference in the involved knee compared to normal or what is assumed to be normal: • Normal (–1-2 mm) • Nearly normal (3-5 mm) • Abnormal (6-10 mm) • Severely abnormal (>10 mm)
Measurement properties	No quality studies have assessed varus stress test

CLINICAL GUIDELINES

Interventions

A plethora of interventions have been described for the treatment of knee instability. A preponderance of evidence from high-quality randomized controlled trials and systematic reviews exists to support the benefits of physical therapy interventions in these patients.

CONTINUOUS PASSIVE MOTION

III A systematic review by Wright et al,[174] which included 6 randomized controlled trials published through 2005, concluded there is no substantial advantage for the use of continuous passive motion except for a possible decrease in pain in patients following ACL reconstruction. However, these studies included a small sample of patients and blinding of the examiners was not addressed.

III A separate systematic review by Smith and Davies,[149] which included 8 papers published between 1992 and 2006, concluded that there was no difference between those who received continuous passive motion and those who did not with regard to joint laxity, functional outcomes, postoperative complications, radiological changes, ecchymoses, and muscle atrophy. Insufficient evidence exists in regards to range of motion, pain, swelling, blood loss, patient satisfaction, or duration of hospital stay. Many methodological limitations were identified in the reviewed studies, such as poor documentation of postoperative management, randomization, recruitment, short follow-ups, and small sample sizes.

C Clinicians can consider using continuous passive motion in the immediate postoperative period to decrease postoperative pain.

EARLY WEIGHT BEARING

II Wright et al[174] conducted a systematic review and found 1 randomized trial that investigated the efficacy of immediate weight bearing versus delayed weight bearing following ACL reconstruction. No deleterious effects of early weight bearing were found regarding stability or function. Anterior knee pain may be decreased with early weight bearing.

V As the forces transmitted to the MCL are very low (less than 20 N) during normal gait,[147] the current standard of care for patients with isolated MCL injuries is to allow weight bearing to tolerance.[123,130] Following repair to the MCL, non-weight bearing is recommended for the initial 3 weeks with weight-bearing as tolerated at 3 weeks[123] but effects of early weight bearing are unknown following MCL injury or repair to the MCL.

V Little evidence exists regarding weight bearing status following PCL injuries, but to protect the healing structures, partial weight bearing status is recommended for 2 to 4 weeks following PCL surgery.[74]

V The initial fixation may be tenuous and vulnerable to failure if stressed too early following multiligament knee surgery. Following multiligament knee surgeries, no weight bearing for the first week and limited weight bearing for the first 6 weeks is recommended[107,132] but effects of early weight bearing are unknown following multiligament knee surgery.

C Early weight bearing can be used for patients following ACL reconstruction without incurring detrimental effects on stability or function.

KNEE BRACING

II Swirtum and associates[156] performed a prospective randomized study to investigate the efficacy of a functional knee brace during early treatment following acute ACL rupture. Ninety-five consecutive patients were included. Randomization was performed by 2 of the authors. Forty-two patients completed the study with 22 in the brace group and 20 in the control group. From 6 to 12 weeks postinjury, subjects in the brace group reported significantly less sense of instability as measured by visual analog scale (VAS). This difference disappeared after 12 weeks. At baseline, the braced group had lower scores on the Knee Osteoarthritis Outcome Score (KOOS) than the control group. No differences were seen at baseline in the Cincinnati Knee Score. At all follow-up periods, no differences were seen in the KOOS or the Cincinnati Score.

III Kocher et al[82] investigated the effect of functional knee bracing on subsequent knee injury in 180 professional skiers with ACL deficiency over a 7-year period. The use of functional bracing was determined by doctor/patient decision making with 101 skiers in the braced group and 79 in the nonbraced group. A subsequent knee injury was defined as an injury that resulted in any loss of work days. Twelve subsequent knee injuries occurred over the study period. A significantly higher proportion of injuries occurred in the nonbraced group (13%), as compared to the braced group (2%). Nonbraced professional skiers with ACL deficiency have 6.4 times greater risk of sustaining a subsequent knee injury compared to braced skiers. When controlling for multiple factors, nonbraced skiers had 8 times greater odds for sustaining a subsequent knee injury compared to braced skiers.

C

The use of functional knee bracing appears to be more beneficial than not using a brace in patients with ACL deficiency.

I

Birmingham et al[17] conducted a randomized controlled clinical trial to compare the effectiveness of a functional knee brace as compared to a neoprene sleeve in postoperative outcomes in patients following ACL reconstruction. No significant differences were found between groups for quality of life, knee laxity, hop LSI, and activity level at 12 and 24 months.

III

Eleven articles published through 2005 were included in a recent systematic review.[173] No evidence supported the routine use of postoperative bracing following ACL reconstruction. No increases in postoperative injuries, increased pain, decreased range of motion, or increased knee laxity were found in the control groups that were not braced following surgery.[174] However, many of the studies did not address or control for potential biases.[173]

V

Recent surveys show that approximately 50% to 60% of orthopaedic surgeons still use bracing in the early postoperative period following ACL surgery.[5,100] Marx et al[101] reported that 62.9% of the orthopaedic surgeons indicated that they recommend a brace for participation in sports postoperatively.

B

The use of immediate postoperative knee bracing appears to be no more beneficial than not using a brace in patients following ACL reconstruction.

I

McDevitt et al[105] prospectively followed 100 service academy candidates with ACL reconstruction. Patients were randomly assigned to a braced or nonbraced group. Both groups wore a knee brace or immobilizer in full knee extension for the first 3 weeks following surgery. The braced group then had the knee brace adjusted to full extension to near full flexion from 3 to 6 weeks postoperatively. At 6 weeks, the braced group wore an off-the-shelf functional brace daily for 6 months and for all rigorous activities for a minimum of 1 year. The nonbraced group had all braces discontinued after 3 weeks. The mean final follow-up period was 29 months. Three subjects who were not braced and 2 subjects who were braced sustained subsequent knee injuries during the follow-up period. No significant differences were found between groups in range of motion, quadriceps strength, single-limb single hop for distance, knee laxity, IKDC scores, and radiographs.

II

In a prospective cohort study to identify the efficacy of functional bracing on subsequent knee injuries following ACL reconstruction, Sterett and associates[153] recruited 820 skiers who had ACL reconstruction at least 2 years prior to the study. Two hundred fifty-seven skiers self-selected the use of a functional knee brace based on a shared doctor/patient decision-making process. A knee injury was defined as any injury to the knee that resulted in missed time from work for any time period. Sixty-one reinjuries occurred over the 7-year study period. The injury rate for the nonbraced group was 9% and for the braced group 4% (P = .009). The nonbraced group had a 2.74 greater odds of sustained a subsequent knee injury and a 3.9 greater odds of knee reinjury requiring surgery as compared to the braced group.

D

Conflicting evidence exists for the use of functional knee bracing in patients following ACL reconstruction.

V

Knee bracing is typically not recommended following nonoperative PCL injuries.[74] But some recommend initial protective bracing with progression to full extension when the posterior knee pain resolves.[170] In regards to postoperative care, a hinged brace is typically used locked in full knee extension for 2 to 4 weeks to avoid the effects of gravity and the forces applied by the hamstrings.[74,170] No current evidence exists that bracing prevents posterior tibial translation.

V

The New Zealand Guideline Group[5] believe that bracing is beneficial for severe grade II and grade III ruptures of the MCL for the first 4 to 6 weeks to stabilize the knee to allow ligament healing to occur. Following surgery to the MCL, a long hinged brace allowing 30° to 90° of knee motion for the first 3 weeks followed by progressive weaning off the brace starting at week 6 is recommended.[123]

V

For the first 4 weeks following multiligament surgery, patients are required to wear a postoperative knee brace locked in full knee extension with progressive flexion thereafter.[107] A medial unloader functional brace is recommended for patients with PLC injuries to be worn during light and full activity.[107]

F — Knee bracing can be used for patients with acute PCL injuries, severe MCL injuries, or PLC injuries.

IMMEDIATE VERSUS DELAYED MOBILIZATION

I — In a prospective study, Ito and colleagues[72] evaluated the results of 3-day immobilization as compared to 2-week immobilization following ACL hamstring graft reconstruction. Thirty consecutive patients underwent multistranded hamstring graft ACL reconstruction and were equally randomized to 1 of 2 groups: 3-day immobilization and 2-week immobilization. Anterior laxity, joint position sense, and thigh muscle strength were measured at 3, 6, and 12 months postsurgery. No significant differences were noted between groups at all time periods.

II — Beynnon et al[13] evaluated 5 randomized controlled trials on the effects of immediate knee motion as compared to delayed knee motion following ACL reconstruction. Although, the method of randomization was described in only 1 study, patients' lost to follow-up was minimal in 2 trials, and no study stated if the investigators were blinded, the authors of the review concluded early joint motion after reconstruction of the ACL appears to be beneficial with reduction in pain, lesser adverse changes to the articular cartilage, and helping prevent the formation of scar and capsular contractions that have the potential to limit joint motion.[15]

V — Harner and Hoher[55] discussed the current concepts on the evaluation and treatment of PCL injuries. They recommend a 2- to 4-week period of immobilization in full extension following a grade III PCL injury to maintain reduction of the tibia and minimize posterior sag to limit forces on the damaged PCL and posterolateral structures. The same recommendations apply following surgery to repair the PCL.

B — Clinicians should consider the use of immediate mobilization following ACL reconstruction to increase range of motion, reduce pain, and limit adverse changes to soft tissue structures.

CRYOTHERAPY

II — Raynor et al[128] performed a meta-analysis on the effects on cryotherapy on early postoperative pain, early postoperative drainage, and early knee range of motion after ACL reconstruction. Seven randomized clinical trials were included and combined for this meta-analysis. Six studies were included for pain with 2 studies showing at least a significant reduction in pain, whereas 4 showed no or minimal improvement. However, 2 of the studies had data extracted from graphical displays. Therefore, the remaining 4 studies showed only marginally significant improvement in pain for the treatment group. Four of the studies that were included evaluated postoperative drainage and only 1 demonstrated a significant improvement with the use of cryotherapy. Of the 4 studies that evaluated postoperative knee range of motion, none demonstrated a significant improvement with cryotherapy. Based on this meta-analysis, patients who received cryotherapy experienced significantly less postoperative pain, but no reduction in postoperative drainage or improvement in early knee range of motion after ACL reconstruction.

C — Clinicians should consider the use of cryotherapy to reduce postoperative knee pain immediately post-ACL reconstruction.

SUPERVISED REHABILITATION

I — The Cochrane collaboration on exercises for treating ACL injuries in combination with collateral ligament and meniscal damage of the knee in adults[164] included only 1 trial comparing supervised training group and home exercise group in patients with ACL deficiency. They concluded that there were no significant differences between groups in the outcome measures. Significantly higher strength measures were found in isometric knee flexion and isokinetic knee flexion and extension in the supervised group.

I — The Cochrane collaboration on exercises for treating isolated ACL injuries in adults[163] that included 2 randomized controlled studies concluded that there was no differences between home-based rehabilitation group and supervised rehabilitation group following ACL surgery in Lysholm scores at 12 weeks or Tegner scores (percent change) at 6 months.

II — Four randomized controlled trials were included in a systematic review to evaluate standard clinic-based physical therapy rehabilitation as compared to minimally supervised home-based rehabilitation following ACL reconstruction.[174] Minimally supervised home-based rehabilitation consists of patients attending 3 to 6 visits with a physical therapist in the clinic to supervise the home-based program. They concluded that a minimally supervised home-based regimen can be successful in restoring function in patients following ACL surgery.

B — Clinicians should consider the use of exercises as part of the in-clinic program, supplemented by a prescribed home-based program supervised by a physical therapist in patients with knee stability and movement coordination impairments.

THERAPEUTIC EXERCISES

II

In a randomized controlled study, Tagesson and colleagues[157] showed that non–weight-bearing (open chain) exercises was more effective in increasing isokinetic knee extension force ($P<.009$) than weight-bearing (closed chain) exercises in patients with ACL deficiency following 4 months of rehabilitation. The LSI for isokinetic knee extension for those training with non–weight-bearing (NWB) exercises was 96% (SD ± 14%) compared to 84% (SD ± 15%) for those training with weight-bearing exercises. No differences were demonstrated in isokinetic knee flexion force, 1 repetition maximum squat, single-limb vertical jump, single-limb single hop for distance, or functional outcomes. This did not include long-term follow-up.

II

Perry et al,[120] in a randomized, single-blind clinical trial, investigated the effects between non-weight-bearing and weight-bearing exercises on function and laxity in patients with ACL deficiency. Patients underwent a 6-week training program. Results showed no differences between groups in knee joint laxity, outcome scores, and functional performance.

I

In the Cochrane review by Trees et al,[163] no differences were found between groups using non–weight-bearing and weight-bearing exercises following ACL reconstruction in knee function, patellofemoral pain severe enough to restrict activity at 1 year, or knee laxity at 1 year. When weight-bearing and non–weight-bearing combined rehabilitation was compared to weight-bearing rehabilitation only, return to sport at 2.5 years was significantly more common in the combined group compared to the weight-bearing exercises only group but no differences were noted in knee laxity or isokinetic quadriceps strength at 6 months.

I

Five prospectively randomized studies following ACL reconstruction were included in a systematic review by Wright and colleagues.[175] Their findings were inconclusive regarding the use and timing of non–weight-bearing and weight-bearing exercises following ACL reconstruction. The studies had a short follow-up period or lacked power for the reviewers to make reasonable conclusions.

V

In a current concepts commentary by Harner and Hoher,[55] they recommend quadriceps muscle strengthening to counteract the posterior tibial subluxation that could occur post-PCL injury and discourage hamstring strengthening as the hamstring loading can increase forces on the PCL.

A

Clinicians should consider the use of non–weight-bearing (open-chain) exercises in conjunction with weight-bearing (closed-chain) exercises in patients with knee stability and movement coordination impairments.

NEUROMUSCULAR ELECTRICAL STIMULATION

I

Fourteen randomized controlled trials have evaluated the use of electrical stimulation during ACL rehabilitation.[175] A variety of parameters for the electrical stimulation were used, making generalized conclusions difficult. Improved isokinetic strength was noted in some studies with no correlation with patient outcomes or functional performance. However, neuromuscular stimulation may improve quadriceps strength if applied in a high-intensity setting (2500-Hz alternating current at 75 burst per second, 2 to 3 times per week for 3 to 12 weeks, for 10 to 15 seconds on with 50-second rest period[33,42,150]) early in the rehabilitation process.

B

Neuromuscular electrical stimulation can be used with patients following ACL reconstruction to increase quadriceps muscle strength.

NEUROMUSCULAR REEDUCATION

Neuromuscular reeducation or neuromuscular (proprioceptive) training has been defined as movement training progressions that facilitate the development of multijoint neuromuscular engrams that combine joint stabilization, acceleration, deceleration, and kinesthesia through intermittent protocols that progress from low intensity movements focused in a single plane to multiplanar power training.[59]

I

Cooper et al[29] performed a systematic review that included 4 randomized clinical studies that investigated the use of proprioceptive and traditional strengthening exercises in individuals with ACL deficiency. Improvements in joint position sense were inconclusive based on the variety of testing procedures used. Limited improvements were noted in muscle strength, subjective rating, and hop testing following neuromuscular training when compared to traditional strengthening in patients with ACL deficiency.

II

Risberg et al[133] conducted a single-blinded, randomized controlled trial (n = 74) to determine the effect of a 6-month neuromuscular training program versus a traditional strength training program following ACL reconstruction. At 6 months, the neuromuscular training group had significantly higher scores in the Cincinnati Knee Score (*P* = .05) and visual analog scale for knee function as compared with the strength training group. No significant differences were exhibited in knee laxity, pain, functional performance, proprioception, and muscle strength. The authors concluded that neuromuscular exercises should be a part of ACL reconstruction rehabilitation. However, no long-term follow-up was performed.

I In the Cochrane systematic review by Trees et al,[164] 1 study investigated supplementary proprioceptive and balance training as compared to traditional strength training in patients following ACL reconstruction. No differences were observed between groups in Lysholm scores or hop tests, but there was significantly more knee flexion range of motion in the group with supplementary training versus the strengthening group.

II Fitzgerald et al[40]examined the efficacy of augmenting standard nonoperative ACL care with a specialized perturbation training program. Using the same decision making as previously used by Fitzgerald et al[39], 26 subjects qualified and completed training. Fourteen subjects were randomized to the standard treatment group and 12 subjects were randomized to the perturbation group. Standard rehabilitation consisted of lower extremity strengthening, cardiovascular endurance training, and agility and sport-specific skill training. Perturbation training is a specialized neuromuscular training program designed to aid in the development of dynamic knee stability among individuals with complete ACL rupture.[40,65] In this study, perturbation training involved maintaining lower extremity balance during the disruption of support surfaces using 3 techniques: rockerboard, rollerboard, and rollerboard with stationary platform.[40,65] All subjects underwent 10 treatment sessions. Subjects who received perturbation training were 4.88 times more likely to have a successful outcome than those who received standard rehabilitation. Subjects in both groups showed an increase in their outcomes scores from pretraining to posttraining. However, the group means remained high in the perturbation training group at 6-month follow-up.

B Clinicians should consider the use of neuromuscular reeducation as a supplementary program to strength training in patients with knee stability and movement coordination impairments.

"ACCELERATED" REHABILITATION

In the 1970s and early 80s the knee was immobilized for 6 to 12 weeks in casts after ACL reconstruction. Return to sporting activities took more than 12 months.[16,174] Over the past 20 years, rehabilitation programs has been evolving, first allowing protected motion and in the 1990s toward early restoration of knee extension, early quadriceps activity, and immediate full weight bearing activities. Earlier return to sporting activities followed, although evidence for adequate healing and effects on reinjury as a consequence of earlier return to sports is unknown.[16,144,174]

The concept of "accelerated" rehabilitation put forth by Shelbourne and Nitz[146] and characterized by immediate restoration of full knee extension or hyperextension equal to the uninvolved side, early weight-bearing exercise and activity, and return to sports "when the knee feels ready," as early as 2 to 3 months after ACL reconstruction has not been examined in any randomized trials. There are 2 randomized controlled trials that have compared programs that are faster with ones that are slower, but neither tested the protocol advocated by Shelbourne and Nitz.

II Trees et al,[164] in the Cochrane systematic review, described 1 such study that found no significant differences between groups in any KOOS domains with mixed physical performance reports over the 2-year follow-up period.

II Similarly in the systematic review by Wright and colleagues,[175] 2 randomized controlled trials were analyzed and no significant conclusions could be made pertaining to the differences in a 6-month rehabilitation compared to an 8-month rehabilitation program. In the second trial, a 19-week program yielded no more deleterious effects than a 32-week program.

B Rehabilitation that emphasizes early restoration of knee extension and early weight-bearing activity appears safe for patients with ACL reconstruction. No evidence exists to determine the efficacy and/or safety of early return to sports.

ECCENTRIC STRENGTHENING

II In a randomized, matched clinical trial (n = 32), Gerber et al[47] investigated the safety, feasibility, and efficacy of a 12-week negative work exercise via eccentric contractions program at 26 weeks postsurgery in patients with ACL reconstruction. Patients were randomly assigned to either a traditional or eccentric exercise program. The progressive negative work exercise was performed using an eccentric exercise ergometer. Knee extension strength and functional performance in the involved limb showed significantly greater improvement for those in the eccentric group as compared to those in the traditional group. Tegner activity scores, from preinjury to 26 weeks postsurgery, decreased to a greater extent in the eccentric group compared to the traditional group. No significant differences were noted between groups in knee or thigh pain, knee effusion, or knee joint laxity.

I Gerber and colleagues[46] evaluated the effectiveness of early progressive eccentric exercise at 1 year following ACL reconstruction. Patients were initially matched randomized into 2 groups: progressive eccentric exercise or standard rehabilitation. Training programs were conducted over a 12-week period. The progressive negative work exercise was performed using an eccentric exercise ergometer. Thirty-two patients (n = 17 in progressive eccentric group and n = 15 in standard rehabilitation) completed a 1-year follow-up. The results demonstrated greater muscle volume improvement in the quadriceps and gluteus maximus in the eccentric group as compared to the standard group ($P \leqslant .05$). Knee extension strength and functional performance improvements were noted in the involved limb in the eccentric group at 1-year follow-up compared to pretraining levels, whereas no improvements were noted in the standard group.

II MacLean and associates[93] evaluated the efficacy of a home eccentric exercise program in improving strength, knee function, and symptoms in athletes with PCL injury. Thirteen athletes with isolated PCL injury underwent 12 weeks of a home-based progressive and systematic eccentric squat program. Quadriceps and hamstrings eccentric and concentric torques at 60° and 120° per second, single-limb hop test, and Lysholm Knee scale scores were compared to 13 healthy sedentary subjects. In the treatment group, significant increases were noted in eccentric and concentric torques. Knee function and symptoms were improved over the 12-week period. The quadriceps in the involved limb showed significantly greater improvement in eccentric torque than in concentric torque following eccentric training. Despite lower eccentric torque in the treatment group as compared to the control group prior to training, no differences existed posttraining.

B Clinicians should consider the use of an eccentric exercise ergometer in patients following ACL reconstruction to increase muscle strength and functional performance. Clinicians should consider the use of eccentric squat program in patients with PCL injury to increase muscle strength and functional performance.

CLINICAL GUIDELINES

Summary of Recommendations

B **RISK FACTORS**

Clinicians should consider the shoe-surface interaction, increased body mass index, narrow femoral notch width, increased joint laxity, preovulatory phase of the menstrual cycle in females, combined loading pattern, and strong quadriceps activation during eccentric contractions as predisposing factors for the risk of sustaining a noncontact anterior cruciate ligament (ACL) injury.

A **DIAGNOSIS/CLASSIFICATION**

Passive knee instability, joint pain, joint effusion, and movement coordination impairments are useful clinical findings for classifying a patient with knee instability into the following International Statistical Classification of Diseases and Related Health Problems (ICD) categories: Sprain and strain involving collateral ligament of knee, Sprain and strain involving cruciate ligament of knee, Injury to multiple structures of knee; and the associated International Classification of Functioning, Disability, and Health (ICF) impairment-based category of knee instability (b7150 Stability of a single joint) and movement coordination impairments (b7601 Control of complex voluntary movements).

B **DIFFERENTIAL DIAGNOSIS**

Clinicians should consider diagnostic classifications associated with serious pathological conditions or psychosocial factors when the patient's reported activity limitations or impairments of body function and structure are not consistent with those presented in the diagnosis/classification section of this guideline or when the patient's symptoms are not resolving with interventions aimed at normalization of the patient's impairments of body function.

A **EXAMINATION – OUTCOME MEASURES**

Clinicians should use a validated patient-reported outcome measure with a general health questionnaire, along with a validated activity scale for patients with knee stability and movement coordination impairments. These tools are useful for identifying a patient's baseline status relative to pain, function, and disability and for monitoring changes in the patient's status throughout the course of treatment.

C **EXAMINATION – ACTIVITY LIMITATION MEASURES**

Clinicians should utilize easily reproducible physical performance measures, such as single-limb hop tests, to assess activity limitation and participation restrictions associated with their patient's knee stability and movement coordination impairments, to assess the changes in the patient's level of function over the episode of care, and to classify and screen knee stability and movement coordination.

C **INTERVENTIONS – CONTINUOUS PASSIVE MOTION**

Clinicians can consider using continuous passive motion in the immediate postoperative period to decrease postoperative pain.

C **INTERVENTIONS – EARLY WEIGHT BEARING**

Early weight-bearing can be used for patients following ACL reconstruction without incurring detrimental effects on stability or function.

C **INTERVENTIONS – KNEE BRACING**

The use of functional knee bracing appears to be more beneficial than not using a brace in patients with ACL deficiency.

B The use of immediate postoperative knee bracing appears to be no more beneficial than not using a brace in patients following ACL reconstruction.

D Conflicting evidence exists for the use of functional knee bracing in patients following ACL reconstruction.

F Knee bracing can be used for patients with acute PCL injuries, severe MCL injuries, or PLC injuries.

B **INTERVENTIONS – IMMEDIATE VERSUS DELAYED MOBILIZATION**

Clinicians should consider the use of immediate mobilization following ACL reconstruction to increase range of motion, reduce pain, and limit adverse changes to soft tissue structures.

C **INTERVENTIONS – CRYOTHERAPY**

Clinicians should consider the use of cryotherapy to reduce postoperative knee pain immediately post-ACL reconstruction.

B **INTERVENTIONS – SUPERVISED REHABILITATION**

Clinicians should consider the use of exercises as part of the in-clinic program, supplemented by a prescribed home-based program supervised by a physical therapist in patients with knee stability and movement coordination impairments.

A **INTERVENTIONS – THERAPEUTIC EXERCISES**

Clinicians should consider the use of non–weight-bearing (open chain) exercises in conjunction with weight-bearing (closed-chain) exercises in patients with knee stability and movement coordination impairments

B **INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION**

Neuromuscular electrical stimulation can be used with patients following ACL reconstruction to increase quadriceps muscle strength.

B INTERVENTIONS – NEUROMUSCULAR REEDUCATION

Clinician should consider the use of neuromuscular training as a supplementary program to strength training in patients with knee stability and movement coordination impairments.

B INTERVENTIONS – "ACCELERATED" REHABILITATION

Rehabilitation that emphasizes early restoration of knee extension and early weight-bearing activity appears safe for patients with ACL reconstruction. No evidence exists to determine the efficacy and/or safety of early return to sports.

B INTERVENTIONS – ECCENTRIC STRENGTHENING

Clinicians should consider the use of an eccentric exercise ergometer in patients following ACL reconstruction to increase muscle strength and functional performance. Clinicians should consider the use of eccentric squat program in patients with PCL injury to increase muscle strength and functional performance.

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REFERENCES

1. Ageberg E, Pettersson A, Friden T. 15-year follow-up of neuromuscular function in patients with unilateral nonreconstructed anterior cruciate ligament injury initially treated with rehabilitation and activity modification: a longitudinal prospective study. *Am J Sports Med.* 2007;35:2109-2117. http://dx.doi.org/10.1177/0363546507305018
2. Ageberg E, Thomee R, Neeter C, Silbernagel KG, Roos EM. Muscle strength and functional performance in patients with anterior cruciate ligament injury treated with training and surgical reconstruction or training only: a two to five-year followup. *Arthritis Rheum.* 2008;59:1773-1779. http://dx.doi.org/10.1002/art.24066
3. Amis AA, Gupte CM, Bull AM, Edwards A. Anatomy of the posterior cruciate ligament and the meniscofemoral ligaments. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:257-263. http://dx.doi.org/10.1007/s00167-005-0686-x
4. AOSSM. IKDC Knee Forms. Available at: http://www.sportsmed.org/tabs/research/downloads/IKDC%202000-Revised%20Subjective%20Scoring.pdf. Accessed Feb 12, 2000.
5. Arroll B, Robb G, Sutich E. The Diagnosis and Management of Soft Tissue Knee Injuries: Internal Derangements. Available at: http://www.nzgg.org.nz/guidelines/0009/ACC_Soft_Tissue_Knee_Injury_Fulltext.pdf. Accessed Feb 12, 2003.
6. Axe MJ, Snyder-Mackler L. Operative and post-operative management of the knee. In: Wilmarth MA, eds. *Postoperative Management of Orthopaedic Surgeries.* La Crosse, WI: Orthopaedic Section, APTA Inc; 2005.
7. Bachmann LM, Haberzeth S, Steurer J, ter Riet G. The accuracy of the Ottawa knee rule to rule out knee fractures: a systematic review. *Ann Intern Med.* 2004;140:121-124.
8. Bahk MS, Cosgarea AJ. Physical examination and imaging of the lateral collateral ligament and posterolateral corner of the knee. *Sports Med Arthrosc.* 2006;14:12-19.
9. Barber SD, Noyes FR, Mangine RE, McCloskey JW, Hartman W. Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. *Clin Orthop Relat Res.* 1990;204-214.
10. Barber-Westin SD, Noyes FR, McCloskey JW. Rigorous statistical reliability, validity, and responsiveness testing of the Cincinnati knee rating system in 350 subjects with uninjured, injured, or anterior cruciate ligament-reconstructed knees. *Am J Sports Med.* 1999;27:402-416.
11. Beall DP, Googe JD, Moss JT, et al. Magnetic resonance imaging of the collateral ligaments and the anatomic quadrants of the knee. *Radiol Clin North Am.* 2007;45:983-1002, vi. http://dx.doi.org/10.1016/j.rcl.2007.08.006
12. Benjaminse A, Gokeler A, van der Schans CP. Clinical diagnosis of an anterior cruciate ligament rupture: a meta-analysis. *J Orthop Sports Phys Ther.* 2006;36:267-288. http://dx.doi.org/10.2519/jospt.2006.2011
13. Beynnon BD, Johnson RJ, Abate JA, Fleming BC, Nichols CE. Treatment of anterior cruciate ligament injuries, part 2. *Am J Sports Med.* 2005;33:1751-1767. http://dx.doi.org/10.1177/0363546505279922
14. Beynnon BD, Johnson RJ, Abate JA, Fleming BC, Nichols CE. Treatment of anterior cruciate ligament injuries, part I. *Am J Sports Med.* 2005;33:1579-1602. http://dx.doi.org/10.1177/0363546505279913
15. Beynnon BD, Johnson RJ, Fleming BC. The science of anterior cruciate ligament rehabilitation. *Clin Orthop Relat Res.* 2002;9-20.
16. Beynnon BD, Uh BS, Johnson RJ, et al. Rehabilitation after anterior cruciate ligament reconstruction: a prospective, randomized, double-blind comparison of programs administered over 2 different time intervals. *Am J Sports Med.* 2005;33:347-359.
17. Birmingham TB, Bryant DM, Giffin JR, et al. A randomized controlled trial comparing the effectiveness of functional knee brace and neoprene sleeve use after anterior cruciate ligament reconstruction. *Am J Sports Med.* 2008;36:648-655.
18. Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. *J Orthop Sports Phys Ther.* 1997;26:138-142.
19. Bradley J, Honkamp NJ, Jost P, West R, Norwig J, Kaplan LD. Incidence and variance of knee injuries in elite college football players. *Am J Orthop (Belle Mead NJ).* 2008;37:310-314.
20. Briggs KK, Kocher MS, Rodkey WG, Steadman JR. Reliability, validity, and responsiveness of the Lysholm knee score and Tegner activity scale for patients with meniscal injury of the knee. *J Bone Joint Surg Am.* 2006;88:698-705. http://dx.doi.org/10.2106/JBJS.E.00339
21. Brukner P, Khan K. *Clinical Sports Medicine.* 3rd ed. Sydney, Australia: McGraw-Hill Australia; 2006.
22. Butler DL, Noyes FR, Grood ES. Ligamentous restraints to anterior-posterior drawer in the human knee. A biomechanical study. *J Bone Joint Surg Am.* 1980;62:259-270.
23. Cascio BM, Culp L, Cosgarea AJ. Return to play after anterior cruciate ligament reconstruction. *Clin Sports Med.* 2004;23:395-408, ix. http://dx.doi.org/10.1016/j.csm.2004.03.004
24. Childs JD, Cleland JA, Elliott JM, et al. Neck pain: clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopedic Section of the American Physical Therapy Association. *J Orthop Sports Phys Ther.* 2008;38:A1-A34. http://dx.doi.org/10.2519/jospt.2008.0303
25. Chmielewski TL, Jones D, Day T, Tillman SM, Lentz TA, George SZ. The association of pain and fear of movement/reinjury with function during anterior cruciate ligament reconstruction rehabilitation. *J Orthop Sports Phys Ther.* 2008;38:746-753. http://dx.doi.org/10.2519/jospt.2008.2887
26. Chmielewski TL, Stackhouse S, Axe MJ, Snyder-Mackler L. A prospective analysis of incidence and severity of quadriceps inhibition in a consecutive sample of 100 patients with complete acute anterior cruciate ligament rupture. *J Orthop Res.* 2004;22:925-930. http://dx.doi.org/10.1016/j.orthres.2004.01.007
27. Cibere J, Bellamy N, Thorne A, et al. Reliability of the knee examination in osteoarthritis: effect of standardization. *Arthritis Rheum.* 2004;50:458-468. http://dx.doi.org/10.1002/art.20025
28. Clapper MP, Wolf SL. Comparison of the reliability of the Orthoranger and the standard goniometer for assessing active lower extremity range of motion. *Phys Ther.* 1988;68:214-218.
29. Cooper RL, Taylor NF, Feller JA. A systematic review of the effect of proprioceptive and balance exercises on people with an injured or reconstructed anterior cruciate ligament. *Res Sports Med.* 2005;13:163-178.
30. Cooperman JM, Riddle DL, Rothstein JM. Reliability and validity of judgments of the integrity of the anterior cruciate ligament of the knee using the Lachman's test. *Phys Ther.* 1990;70:225-233.
31. de Jong SN, van Caspel DR, van Haeff MJ, Saris DB. Functional assessment and muscle strength before and after reconstruction of chronic anterior cruciate ligament lesions. *Arthroscopy*. 2007;23:21-28 e21-23.
32. Delay BS, Smolinski RJ, Wind WM, Bowman DS. Current practices and opinions in ACL reconstruction and rehabilitation: results of a survey of the American Orthopaedic Society for Sports Medicine. *Am J Knee Surg.* 2001;14:85-91.
33. Delitto A, Rose SJ, McKowen JM, Lehman RC, Thomas JA, Shively RA. Electrical stimulation versus voluntary exercise in strengthening thigh musculature after anterior cruciate ligament surgery. *Phys Ther.* 1988;68:660-663.

34. Duthon VB, Barea C, Abrassart S, Fasel JH, Fritschy D, Menetrey J. Anatomy of the anterior cruciate ligament. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:204-213. http://dx.doi.org/10.1007/s00167-005-0679-9

35. Eakin CL, Cannon WD, Jr. Arthrometric evaluation of posterior cruciate ligament injuries. *Am J Sports Med.* 1998;26:96-102.

36. Fanelli GC. Posterior cruciate ligament injuries in trauma patients. *Arthroscopy*. 1993;9:291-294.

37. Fanelli GC, Edson CJ. Posterior cruciate ligament injuries in trauma patients: Part II. *Arthroscopy*. 1995;11:526-529.

38. Fetto JF, Marshall JL. Medial collateral ligament injuries of the knee: a rationale for treatment. *Clin Orthop Relat Res.* 1978;206-218.

39. Fitzgerald GK, Axe MJ, Snyder-Mackler L. A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture. *Knee Surg Sports Traumatol Arthrosc.* 2000;8:76-82.

40. Fitzgerald GK, Axe MJ, Snyder-Mackler L. The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physical active individuals. *Phys Ther.* 2000;80:128-140.

41. Fitzgerald GK, Lephart SM, Hwang JH, Wainner RS. Hop tests as predictors of dynamic knee stability. *J Orthop Sports Phys Ther.* 2001;31:588-597.

42. Fitzgerald GK, Piva SR, Irrgang JJ. A modified neuromuscular electrical stimulation protocol for quadriceps strength training following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther.* 2003;33:492-501.

43. Flik K, Lyman S, Marx RG. American collegiate men's ice hockey: an analysis of injuries. *Am J Sports Med.* 2005;33:183-187.

44. Frank CB, Jackson DW. The science of reconstruction of the anterior cruciate ligament. *J Bone Joint Surg Am.* 1997;79:1556-1576.

45. George MS, Huston LJ, Spindler KP. Endoscopic versus rear-entry ACL reconstruction: a systematic review. *Clin Orthop Relat Res.* 2007;455:158-161. http://dx.doi.org/10.1097/BLO.0b013e31802eb45f

46. Gerber JP, Marcus RL, Dibble LE, Greis PE, Burks RT, LaStayo PC. Effects of early progressive eccentric exercise on muscle size and function after anterior cruciate ligament reconstruction: a 1-year follow-up study of a randomized clinical trial. *Phys Ther.* 2009;89:51-59. http://dx.doi.org/10.2522/ptj.20070189

47. Gerber JP, Marcus RL, Dibble LE, Greis PE, Burks RT, Lastayo PC. Safety, feasibility, and efficacy of negative work exercise via eccentric muscle activity following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther.* 2007;37:10-18. http://dx.doi.org/10.2519/jospt.2007.2362

48. Girgis FG, Marshall JL, Monajem A. The cruciate ligaments of the knee joint. Anatomical, functional and experimental analysis. *Clin Orthop Relat Res.* 1975;216-231.

49. Grassmayr MJ, Parker DA, Coolican MR, Vanwanseele B. Posterior cruciate ligament deficiency: biomechanical and biological consequences and the outcomes of conservative treatment. A systematic review. *J Sci Med Sport.* 2008;11:433-443. http://dx.doi.org/10.1016/j.jsams.2007.07.007

50. Griffin LY, Agel J, Albohm MJ, et al. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *J Am Acad Orthop Surg.* 2000;8:141-150.

51. Griffin LY, Albohm MJ, Arendt EA, et al. Understanding and preventing noncontact anterior cruciate ligament injuries: a review of the Hunt Valley II meeting, January 2005. *Am J Sports Med.* 2006;34:1512-1532. http://dx.doi.org/10.1177/0363546506286866

52. Grood ES, Noyes FR, Butler DL, Suntay WJ. Ligamentous and capsular restraints preventing straight medial and lateral laxity in intact human cadaver knees. *J Bone Joint Surg Am.* 1981;63:1257-1269.

53. Guyatt GH, Sackett DL, Sinclair JC, Hayward R, Cook DJ, Cook RJ. Users' guides to the medical literature. IX. A method for grading health care recommendations. Evidence-Based Medicine Working Group. *JAMA*. 1995;274:1800-1804.

54. Halinen J, Lindahl J, Hirvensalo E, Santavirta S. Operative and nonoperative treatments of medial collateral ligament rupture with early anterior cruciate ligament reconstruction: a prospective randomized study. *Am J Sports Med.* 2006;34:1134-1140. http://dx.doi.org/10.1177/0363546505284889

55. Harner CD, Hoher J. Evaluation and treatment of posterior cruciate ligament injuries. *Am J Sports Med.* 1998;26:471-482.

56. Harner CD, Irrgang JJ, Paul J, Dearwater S, Fu FH. Loss of motion after anterior cruciate ligament reconstruction. *Am J Sports Med.* 1992;20:499-506.

57. Hewett TE, Ford KR, Myer GD. Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med.* 2006;34:490-498. http://dx.doi.org/10.1177/0363546505282619

58. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med.* 2006;34:299-311. http://dx.doi.org/10.1177/0363546505284183

59. Hewett TE, Paterno MV, Myer GD. Strategies for enhancing proprioception and neuromuscular control of the knee. *Clin Orthop Relat Res.* 2002;76-94.

60. Hewett TE, Zazulak BT, Myer GD. Effects of the menstrual cycle on anterior cruciate ligament injury risk: a systematic review. *Am J Sports Med.* 2007;35:659-668. http://dx.doi.org/10.1177/0363546506295699

61. Hopper DM, Strauss GR, Boyle JJ, Bell J. Functional recovery after anterior cruciate ligament reconstruction: a longitudinal perspective. *Arch Phys Med Rehabil.* 2008;89:1535-1541. http://dx.doi.org/10.1016/j.apmr.2007.11.057

62. Hughes G, Watkins J. A risk-factor model for anterior cruciate ligament injury. *Sports Med.* 2006;36:411-428.

63. Hurd WJ, Axe MJ, Snyder-Mackler L. A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: Part 1, outcomes. *Am J Sports Med.* 2008;36:40-47. http://dx.doi.org/10.1177/0363546507308190

64. Hurd WJ, Axe MJ, Snyder-Mackler L. A 10-year prospective trial of a patient management algorithm and screening examination for highly active individuals with anterior cruciate ligament injury: Part 2, determinants of dynamic knee stability. *Am J Sports Med.* 2008;36:48-56. http://dx.doi.org/10.1177/0363546507308191

65. Hurd WJ, Chmielewski TL, Snyder-Mackler L. Perturbation-enhanced neuromuscular training alters muscle activity in female athletes. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:60-69. http://dx.doi.org/10.1007/s00167-005-0624-y

66. Ibrahim SA, Al-Kussary IM, Al-Misfer AR, Al-Mutairi HQ, Ghafar SA, El Noor TA. Clinical evaluation of arthroscopically assisted anterior cruciate ligament reconstruction: patellar tendon versus gracilis and semitendinosus autograft. *Arthroscopy*. 2005;21:412-417. http://dx.doi.org/10.1016/j.arthro.2004.12.002

67. Indelicato PA. Isolated medial collateral ligament injuries in the knee. *J Am Acad Orthop Surg.* 1995;3:9-14.

68. Indelicato PA, Hermansdorfer J, Huegel M. Nonoperative management of complete tears of the medial collateral ligament of the knee in intercollegiate football players. *Clin Orthop Relat Res.* 1990;174-177.

69. Ingersoll CD, Grindstaff TL, Pietrosimone BG, Hart JM. Neuromuscular consequences of anterior cruciate ligament injury. *Clin Sports Med.*

2008;27:383-404, vii. http://dx.doi.org/10.1016/j.csm.2008.03.004

70. Irrgang JJ, Anderson AF, Boland AL, et al. Responsiveness of the International Knee Documentation Committee Subjective Knee Form. *Am J Sports Med.* 2006;34:1567-1573. http://dx.doi.org/10.1177/0363546506288855

71. Irrgang JJ, Snyder-Mackler L, Wainner RS, Fu FH, Harner CD. Development of a patient-reported measure of function of the knee. *J Bone Joint Surg Am.* 1998;80:1132-1145.

72. Ito Y, Deie M, Adachi N, et al. A prospective study of 3-day versus 2-week immobilization period after anterior cruciate ligament reconstruction. *Knee*. 2007;14:34-38. http://dx.doi.org/10.1016/j.knee.2006.10.004

73. Jackson JL, O'Malley PG, Kroenke K. Evaluation of acute knee pain in primary care. *Ann Intern Med.* 2003;139:575-588.

74. Janousek AT, Jones DG, Clatworthy M, Higgins LD, Fu FH. Posterior cruciate ligament injuries of the knee joint. *Sports Med.* 1999;28:429-441.

75. Kannus P. Long-term results of conservatively treated medial collateral ligament injuries of the knee joint. *Clin Orthop Relat Res.* 1988;103-112.

76. Kastelein M, Wagemakers HP, Luijsterburg PA, Verhaar JA, Koes BW, Bierma-Zeinstra SM. Assessing medial collateral ligament knee lesions in general practice. *Am J Med*. 2008;121:982-988 e982. http://dx.doi.org/10.1016/j.amjmed.2008.05.041

77. Keays SL, Bullock-Saxton JE, Keays AC, Newcombe PA, Bullock MI. A 6-year follow-up of the effect of graft site on strength, stability, range of motion, function, and joint degeneration after anterior cruciate ligament reconstruction: patellar tendon versus semitendinosus and Gracilis tendon graft. *Am J Sports Med.* 2007;35:729-739. http://dx.doi.org/10.1177/0363546506298277

78. Keller PM, Shelbourne KD, McCarroll JR, Rettig AC. Nonoperatively treated isolated posterior cruciate ligament injuries. *Am J Sports Med.* 1993;21:132-136.

79. Kennedy JC, Hawkins RJ, Willis RB, Danylchuck KD. Tension studies of human knee ligaments. Yield point, ultimate failure, and disruption of the cruciate and tibial collateral ligaments. *J Bone Joint Surg Am.* 1976;58:350-355.

80. Kocabey Y, Tetik O, Isbell WM, Atay OA, Johnson DL. The value of clinical examination versus magnetic resonance imaging in the diagnosis of meniscal tears and anterior cruciate ligament rupture. *Arthroscopy*. 2004;20:696-700. http://dx.doi.org/10.1016/j.arthro.2004.06.008

81. Kocher MS, Steadman JR, Briggs KK, Sterett WI, Hawkins RJ. Reliability, validity, and responsiveness of the Lysholm knee scale for various chondral disorders of the knee. *J Bone Joint Surg Am.* 2004;86:1139-1145.

82. Kocher MS, Sterett WI, Briggs KK, Zurakowski D, Steadman JR. Effect of functional bracing on subsequent knee injury in ACL-deficient professional skiers. *J Knee Surg.* 2003;16:87-92.

83. Kostogiannis I, Ageberg E, Neuman P, Dahlberg L, Friden T, Roos H. Activity level and subjective knee function 15 years after anterior cruciate ligament injury: a prospective, longitudinal study of nonreconstructed patients. *Am J Sports Med.* 2007;35:1135-1143. http://dx.doi.org/10.1177/0363546507299238

84. Kvist J, Ek A, Sporrstedt K, Good L. Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2005;13:393-397. http://dx.doi.org/10.1007/s00167-004-0591-8

85. LaPrade RF, Engebretsen AH, Ly TV, Johansen S, Wentorf FA, Engebretsen L. The anatomy of the medial part of the knee. *J Bone Joint Surg Am*. 2007;89:2000-2010. http://dx.doi.org/10.2106/JBJS.F.01176

86. LaPrade RF, Gilbert TJ, Bollom TS, Wentorf F, Chaljub G. The magnetic resonance imaging appearance of individual structures of the posterolateral knee. A prospective study of normal knees and knees with surgically verified grade III injuries. *Am J Sports Med.* 2000;28:191-199.

87. LaPrade RF, Terry GC. Injuries to the posterolateral aspect of the knee. Association of anatomic injury patterns with clinical instability. *Am J Sports Med.* 1997;25:433-438.

88. Lee DY, Karim SA, Chang HC. Return to sports after anterior cruciate ligament reconstruction - a review of patients with minimum 5-year follow-up. *Ann Acad Med Singapore.* 2008;37:273-278.

89. Leeuw M, Goossens ME, Linton SJ, Crombez G, Boersma K, Vlaeyen JW. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. *J Behav Med.* 2007;30:77-94. http://dx.doi.org/10.1007/s10865-006-9085-0

90. Levy AS, Wetzler MJ, Lewars M, Laughlin W. Knee injuries in women collegiate rugby players. *Am J Sports Med.* 1997;25:360-362.

91. Linko E, Harilainen A, Malmivaara A, Seitsalo S. Surgical versus conservative interventions for anterior cruciate ligament ruptures in adults. *Cochrane Database Syst Rev.* 2005;CD001356. http://dx.doi.org/10.1002/14651858.CD001356.pub3

92. Lysholm J, Tegner Y. Knee injury rating scales. *Acta Orthop.* 2007;78:445-453. http://dx.doi.org/10.1080/17453670710014068

93. MacLean CL, Taunton JE, Clement DB, Regan WD, Stanish WD. Eccentric kinetic chain exercise as a conservative means of functionally rehabilitating chronic isolated insufficiency of the posterior cruciate ligament. *Clin J Sport Med.* 1999;9:142-150.

94. Madhusudhan T, Kumar T, Bastawrous S, Sinha A. Clinical examination, MRI and arthroscopy in meniscal and ligamentous knee Injuries - a prospective study. *J Orthop Surg Res.* 2008;3:19. http://dx.doi.org/10.1186/1749-799X-3-19

95. Magee DJ. Knee. In: eds. *Orthopedic Physical Assessment.* Philadelphia, PA: W.B. Saunders Company; 1997:546-637.

96. Majewski M, Susanne H, Klaus S. Epidemiology of athletic knee injuries: a 10-year study. *Knee*. 2006;13:184-188. http://dx.doi.org/10.1016/j.knee.2006.01.005

97. Malone AA, Dowd GS, Saifuddin A. Injuries of the posterior cruciate ligament and posterolateral corner of the knee. *Injury*. 2006;37:485-501. http://dx.doi.org/10.1016/j.injury.2005.08.003

98. Man IO, Markland KL, Morrissey MC. The validity and reliability of the in evaluating human knee volume. *Clin Physiol Funct Imaging.* 2004;24:352-358. http://dx.doi.org/10.1111/j.1475-097X.2004.00577.x

99. Manal TJ, Snyder-Mackler L. Practice guidelines for anterior cruciate ligament rehabilitation: a criterion-based rehabilitation progression. *Oper Tech Orthop.* 1996;6:190-196.

100. Marx RG, Jones EC, Angel M, Wickiewicz TL, Warren RF. Beliefs and attitudes of members of the American Academy of Orthopaedic Surgeons regarding the treatment of anterior cruciate ligament injury. *Arthroscopy*. 2003;19:762-770.

101. Marx RG, Stump TJ, Jones EC, Wickiewicz TL, Warren RF. Development and evaluation of an activity rating scale for disorders of the knee. *Am J Sports Med.* 2001;29:213-218.

102. Mattacola CG, Perrin DH, Gansneder BM, Gieck JH, Saliba EN, McCue FC, 3rd. Strength, functional outcome, and postural stability after anterior cruciate ligament reconstruction. *J Athl Train.* 2002;37:262-268.

103. Mauro CS, Irrgang JJ, Williams BA, Harner CD. Loss of extension following anterior cruciate ligament reconstruction: analysis of incidence and etiology using IKDC criteria. *Arthroscopy*. 2008;24:146-153.

104. Mayr HO, Weig TG, Plitz W. Arthrofibrosis following ACL reconstruction--reasons and outcome. *Arch Orthop Trauma Surg.* 2004;124:518-522. http://dx.doi.org/10.1007/s00402-004-0718-x

105. McDevitt ER, Taylor DC, Miller MD, et al. Functional bracing after anterior cruciate ligament reconstruction: a prospective, randomized, multicenter study. *Am J Sports Med.* 2004;32:1887-1892.

106. McHugh MP, Tyler TF, Gleim GW, Nicholas SJ. Preoperative indicators of motion loss and weakness following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther.* 1998;27:407-411.

107. Medvecky MJ, Zazulak BT, Hewett TE. A multidisciplinary approach to the evaluation, reconstruction and rehabilitation of the multi-ligament injured athlete. *Sports Med.* 2007;37:169-187.

108. Meister BR, Michael SP, Moyer RA, Kelly JD, Schneck CD. Anatomy and kinematics of the lateral collateral ligament of the knee. *Am J Sports Med.* 2000;28:869-878.

109. Mihata LC, Beutler AI, Boden BP. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med.* 2006;34:899-904. http://dx.doi.org/10.1177/0363546505285582

110. Millett PJ, Wickiewicz TL, Warren RF. Motion loss after ligament injuries to the knee. Part I: causes. *Am J Sports Med.* 2001;29:664-675.

111. Moisala AS, Jarvela T, Kannus P, Jarvinen M. Muscle strength evaluations after ACL reconstruction. *Int J Sports Med.* 2007;28:868-872. http://dx.doi.org/10.1055/s-2007-964912

112. Moksnes H, Risberg MA. Performance-based functional evaluation of non-operative and operative treatment after anterior cruciate ligament injury. *Scand J Med Sci Sports.* 2009;19:345-355. http://dx.doi.org/10.1111/j.1600-0838.2008.00816.x

113. Moksnes H, Snyder-Mackler L, Risberg MA. Individuals with an anterior cruciate ligament-deficient knee classified as noncopers may be candidates for nonsurgical rehabilitation. *J Orthop Sports Phys Ther.* 2008;38:586-595. http://dx.doi.org/10.2519/jospt.2008.2750

114. Muaidi QI, Nicholson LL, Refshauge KM, Herbert RD, Maher CG. Prognosis of conservatively managed anterior cruciate ligament injury: a systematic review. *Sports Med.* 2007;37:703-716.

115. Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med.* 1991;19:513-518.

116. Noyes FR, DeLucas JL, Torvik PJ. Biomechanics of anterior cruciate ligament failure: an analysis of strain-rate sensitivity and mechanisms of failure in primates. *J Bone Joint Surg Am.* 1974;56:236-253.

117. Noyes FR, Matthews DS, Mooar PA, Grood ES. The symptomatic anterior cruciate-deficient knee. Part II: the results of rehabilitation, activity modification, and counseling on functional disability. *J Bone Joint Surg Am.* 1983;65:163-174.

118. Patel AA, Donegan D, Albert T. The 36-item short form. *J Am Acad Orthop Surg.* 2007;15:126-134.

119. Patel DV, Allen AA, Warren RF, Wickiewicz TL, Simonian PT. The nonoperative treatment of acute, isolated (partial or complete) posterior cruciate ligament-deficient knees: an intermediate-term follow-up study. *HSS J.* 2007;3:137-146. http://dx.doi.org/10.1007/s11420-007-9058-z

120. Perry MC, Morrissey MC, Morrissey D, Knight PR, McAuliffe TB, King JB. Knee extensors kinetic chain training in anterior cruciate ligament deficiency. *Knee Surg Sports Traumatol Arthrosc.* 2005;13:638-648. http://dx.doi.org/10.1007/s00167-004-0603-8

121. Petersen W, Zantop T. Anatomy of the anterior cruciate ligament with regard to its two bundles. *Clin Orthop Relat Res.* 2007;454:35-47. http://dx.doi.org/10.1097/BLO.0b013e31802b4a59

122. Phillips B, Ball C, Sackett D, et al. Levels of Evidence. Available at: http://www.cebm.net/index.aspx?o = 4590. Accessed Feb 12, 1998.

123. Phisitkul P, James SL, Wolf BR, Amendola A. MCL injuries of the knee: current concepts review. *Iowa Orthop J.* 2006;26:77-90.

124. Piriyaprasarth P, Morris ME. Psychometric properties of measurement tools for quantifying knee joint position and movement: a systematic review. *Knee*. 2007;14:2-8. http://dx.doi.org/10.1016/j.knee.2006.10.006

125. Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy*. 2007;23:1320-1325.

126. Pugh L, Mascarenhas R, Arneja S, Chin PY, Leith JM. Current concepts in instrumented knee-laxity testing. *Am J Sports Med.* 2009;37:199-210. http://dx.doi.org/10.1177/0363546508323746

127. Ramos J, Perrotta C, Badariotti G, Berenstein G. Interventions for preventing venous thromboembolism in adults undergoing knee arthroscopy. *Cochrane Database Syst Rev.* 2008;CD005259. http://dx.doi.org/10.1002/14651858.CD005259.pub3

128. Raynor MC, Pietrobon R, Guller U, Higgins LD. Cryotherapy after ACL reconstruction: a meta-analysis. *J Knee Surg.* 2005;18:123-129.

129. Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther.* 2007;87:337-349. http://dx.doi.org/10.2522/ptj.20060143

130. Reider B. Medial collateral ligament injuries in athletes. *Sports Med.* 1996;21:147-156.

131. Ricchetti ET, Sennett BJ, Huffman GR. Acute and chronic management of posterolateral corner injuries of the knee. *Orthopedics*. 2008;31:479-488; quiz 489-490.

132. Rihn JA, Groff YJ, Harner CD, Cha PS. The acutely dislocated knee: evaluation and management. *J Am Acad Orthop Surg.* 2004;12:334-346.

133. Risberg MA, Holm I, Myklebust G, Engebretsen L. Neuromuscular training versus strength training during first 6 months after anterior cruciate ligament reconstruction: a randomized clinical trial. *Phys Ther.* 2007;87:737-750. http://dx.doi.org/10.2522/ptj.20060041

134. Robertson A, Nutton RW, Keating JF. Dislocation of the knee. *J Bone Joint Surg Br.* 2006;88:706-711. http://dx.doi.org/10.1302/0301-620X.88B6.17448

135. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *J Orthop Sports Phys Ther.* 1998;28:88-96.

136. Ross MD, Langford B, Whelan PJ. Test-retest reliability of 4 single-leg horizontal hop tests. *J Strength Cond Res.* 2002;16:617-622.

137. Rubinstein RA, Jr., Shelbourne KD, McCarroll JR, VanMeter CD, Rettig AC. The accuracy of the clinical examination in the setting of posterior cruciate ligament injuries. *Am J Sports Med.* 1994;22:550-557.

138. Scholten RJ, Opstelten W, van der Plas CG, Bijl D, Deville WL, Bouter LM. Accuracy of physical diagnostic tests for assessing ruptures of the anterior cruciate ligament: a meta-analysis. *J Fam Pract.* 2003;52:689-694.

139. Schulz MS, Russe K, Weiler A, Eichhorn HJ, Strobel MJ. Epidemiology of posterior cruciate ligament injuries. *Arch Orthop Trauma Surg.* 2003;123:186-191.

140. Sgaglione NA, Del Pizzo W, Fox JM, Friedman MJ. Critical analysis of knee ligament rating systems. *Am J Sports Med.* 1995;23:660-667.

141. Shapiro ET, Richmond JC, Rockett SE, McGrath MM, Donaldson WR. The use of a generic, patient-based health assessment (SF-36) for evaluation of patients with anterior cruciate ligament injuries. *Am J Sports Med.* 1996;24:196-200.

142. Shelbourne KD, Davis TJ, Patel DV. The natural history of acute, isolated, nonoperatively treated posterior cruciate ligament injuries. A prospective study. *Am J Sports Med.* 1999;27:276-283.

143. Shelbourne KD, Gray T. Minimum 10-year results after anterior cruciate ligament reconstruction: how the loss of normal knee motion compounds other factors related to the development of osteoarthritis after surgery. *Am J Sports Med.* 2009;37:471-480.

144. Shelbourne KD, Klootwyk TE, Decarlo MS. Update on accelerated rehabilitation after anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther.* 1992;15:303-308.

145. Shelbourne KD, Muthukaruppan Y. Subjective results of nonoperatively treated, acute, isolated posterior cruciate ligament injuries. *Arthroscopy*. 2005;21:457-461. http://dx.doi.org/10.1016/j.arthro.2004.11.013

146. Shelbourne KD, Nitz P. Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am J Sports Med.* 1990;18:292-299.

147. Shelburne KB, Torry MR, Pandy MG. Muscle, ligament, and joint-contact forces at the knee during walking. *Medicine & Science in Sports & Exercise.* 2005;37:1948-1956.

148. Shimokochi Y, Shultz SJ. Mechanisms of noncontact anterior cruciate ligament injury. *J Athl Train.* 2008;43:396-408.

149. Smith T, Davies L. The efficacy of continuous passive motion after anterior cruciate ligament reconstruction: a systematic review. *Phys Ther Sport.* 2007;8:141-152.

150. Snyder-Mackler L, Delitto A, Bailey SL, Stralka SW. Strength of the quadriceps femoris muscle and functional recovery after reconstruction of the anterior cruciate ligament. A prospective, randomized clinical trial of electrical stimulation. *J Bone Joint Surg Am.* 1995;77:1166-1173.

151. Sole G, Hamren J, Milosavljevic S, Nicholson H, Sullivan SJ. Test-retest reliability of isokinetic knee extension and flexion. *Arch Phys Med Rehabil.* 2007;88:626-631. http://dx.doi.org/10.1016/j.apmr.2007.02.006

152. Solomon DH, Simel DL, Bates DW, Katz JN, Schaffer JL. The rational clinical examination. Does this patient have a torn meniscus or ligament of the knee? Value of the physical examination. *Jama*. 2001;286:1610-1620.

153. Sterett WI, Briggs KK, Farley T, Steadman JR. Effect of functional bracing on knee injury in skiers with anterior cruciate ligament reconstruction: a prospective cohort study. *Am J Sports Med.* 2006;34:1581-1585. http://dx.doi.org/10.1177/0363546506289883

154. Stiell IG, Greenberg GH, Wells GA, et al. Derivation of a decision rule for the use of radiography in acute knee injuries. *Ann Emerg Med.* 1995;26:405-413.

155. Sturgill LP, Snyder-Mackler L, Manal TJ, Axe MJ. Interrater reliability of a clinical scale to assess knee joint effusion. *J Orthop Sports Phys Ther.* 2009;39:845-849. http://dx.doi.org/10.2519/jospt.2009.3143

156. Swirtun LR, Jansson A, Renstrom P. The effects of a functional knee brace during early treatment of patients with a nonoperated acute anterior cruciate ligament tear: a prospective randomized study. *Clin J Sport Med.* 2005;15:299-304.

157. Tagesson S, Oberg B, Good L, Kvist J. A comprehensive rehabilitation program with quadriceps strengthening in closed versus open kinetic chain exercise in patients with anterior cruciate ligament deficiency: a randomized clinical trial evaluating dynamic tibial translation and muscle function. *Am J Sports Med.* 2008;36:298-307. http://dx.doi.org/10.1177/0363546507307867

158. Tanner SM, Dainty KN, Marx RG, Kirkley A. Knee-specific quality-of-life instruments: which ones measure symptoms and disabilities most important to patients? *Am J Sports Med.* 2007;35:1450-1458. http://dx.doi.org/10.1177/0363546507301883

159. Tay GH, Warrier SK, Marquis G. Indirect patella fractures following ACL reconstruction: a review. *Acta Orthop.* 2006;77:494-500. http://dx.doi.org/10.1080/17453670610046451

160. Theiler R, Stucki G, Schutz R, et al. Parametric and non-parametric measures in the assessment of knee and hip osteoarthritis: interobserver reliability and correlation with radiology. *Osteoarthritis Cartilage.* 1996;4:35-42.

161. Thomeé P, Währborg P, Börjesson M, Thomeé R, Eriksson BI, Karlsson J. Self-efficacy of knee function as a pre-operative predictor of outcome 1 year after anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc.* 2008;16:118-127.

162. Toritsuka Y, Horibe S, Hiro-Oka A, Mitsuoka T, Nakamura N. Conservative treatment for rugby football players with an acute isolated posterior cruciate ligament injury. *Knee Surg Sports Traumatol Arthrosc.* 2004;12:110-114. http://dx.doi.org/10.1007/s00167-003-0381-8

163. Trees AH, Howe TE, Dixon J, White L. Exercise for treating isolated anterior cruciate ligament injuries in adults. *Cochrane Database Syst Rev.* 2005;CD005316. http://dx.doi.org/10.1002/14651858.CD005316.pub2

164. Trees AH, Howe TE, Grant M, Gray HG. Exercise for treating anterior cruciate ligament injuries in combination with collateral ligament and meniscal damage of the knee in adults. *Cochrane Database Syst Rev.* 2007;CD005961. http://dx.doi.org/10.1002/14651858.CD005961.pub2

165. Tsepis E, Vagenas G, Ristanis S, Georgoulis A. Thigh muscle weakness in ACL-deficient knees persists without structured rehabilitation. *Clin Orthop Relat Res.* 2006;450:211-218.

166. Tzurbakis M, Diamantopoulos A, Xenakis T, Georgoulis A. Surgical treatment of multiple knee ligament injuries in 44 patients: 2-8 years follow-up results. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:739-749. http://dx.doi.org/10.1007/s00167-006-0039-4

167. Uhorchak JM, Scoville CR, Williams GN, Arciero RA, St Pierre P, Taylor DC. Risk factors associated with noncontact injury of the anterior cruciate ligament: a prospective four-year evaluation of 859 West Point cadets. *Am J Sports Med.* 2003;31:831-842.

168. Van Tongel A, Stuyck J, Bellemans J, Vandenneucker H. Septic arthritis after arthroscopic anterior cruciate ligament reconstruction: a retrospective analysis of incidence, management and outcome. *Am J Sports Med.* 2007;35:1059-1063. http://dx.doi.org/10.1177/0363546507299443

169. Warme WJ, Feagin JA, Jr., King P, Lambert KL, Cunningham RR. Ski injury statistics, 1982 to 1993, Jackson Hole Ski Resort. *Am J Sports Med.* 1995;23:597-600.

170. Wind WM, Jr., Bergfeld JA, Parker RD. Evaluation and treatment of posterior cruciate ligament injuries: revisited. *Am J Sports Med.* 2004;32:1765-1775.

171. World Health Organization. International Classification of Functioning, Disability and Health. Geneva, Switzerland: 2001.

172. Wright RW. Knee injury outcomes measures. *J Am Acad Orthop Surg.* 2009;17:31-39.

173. Wright RW, Fetzer GB. Bracing after ACL reconstruction: a systematic review. *Clin Orthop Relat Res.* 2007;455:162-168. http://dx.doi.org/10.1097/BLO.0b013e31802c9360

174. Wright RW, Preston E, Fleming BC, et al. A systematic review of anterior cruciate ligament reconstruction rehabilitation: part I: continuous passive motion, early weight bearing, postoperative bracing, and home-based rehabilitation. *J Knee Surg.* 2008;21:217-224.

175. Wright RW, Preston E, Fleming BC, et al. A systematic review of anterior cruciate ligament reconstruction rehabilitation: part II: open versus closed kinetic chain exercises, neuromuscular electrical stimulation, accelerated rehabilitation, and miscellaneous topics. *J Knee Surg.* 2008;21:225-234.