



THE KNEE

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Knee Stability and Movement Coordination Impairments: Knee Ligament Sprain Revision 2017

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

J Orthop Sports Phys Ther 2017;47(11):A1-A42 doi:10.2519/jospt.2017.0303

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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 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

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Summary of Recommendations*

DIAGNOSIS/CLASSIFICATION

1A Physical therapists should diagnose the International Classification of Diseases (ICD) category of Sprain and strain with subcategory impairment of knee. Sprain and strain involves rupture of one, and repair to maintain structure and use, and the associated International Classification of Functioning, Disability, and Health (ICF) impairment level I category of knee stability (**7150 Stability of a single joint**) and movement coordination impairment (**7150 Coordination of complex voluntary movements**), with the following history and physical examination findings: mechanism of injury, positive Lachman, joint pain, joint effusion, and movement coordination impairment.

DIFFERENTIAL DIAGNOSIS

1B The clinician should suspect diagnostic classification associated with various pathological conditions when the patient self-reported activity limitations and impairments of body function and structure are not consistent with those presented in the Diagnostic Classification section of the guidelines, or when the individual's symptoms are not resolving with observation aimed at normalization of the individual's impairment or body function.

EXAMINATION - OUTCOME MEASURES, ACTIVITY LIMITATIONS AND SELF-REPORTED MEASURES

1C Clinicians should use the International Knee Documentation (IKD) or Knee Injury and Outcome Score (KOOS), and may use the Lysholm scale, an validated patient reported outcome measure to assess knee symptoms and function, and should use the Knee Injury and Outcome Score to assess activity levels, before and after interventions intended to address the clinical problem, such as, joint instability, and joint function restrictions associated with knee ligament injury. Clinicians may use the Anterior Cruciate Ligament Return to Sport after Injury (ACL-RSI) instrument to evaluate patient readiness to return to sport. Clinicians should use psychosocial factors that may hinder return to sports before and after interventions intended to address fear of re-injury associated with knee ligament sprain.

EXAMINATION - PHYSICAL PERFORMANCE MEASURES

1D Clinicians should administer appropriate clinical or field tests, such as, single-legged hop tests, single hop for distance, crossover hop for distance, triple hop for distance, and tandem timing test. Test reliability is affected by the relationship to pain, function, and disability. Tests do not make asymptomatic chronic distal knee dysfunction a patient's readiness to return to activities, and monitor changes in the patient's status throughout the course of treatment.

EXAMINATION - PHYSICAL IMPAIRMENT MEASURES

1E When evaluating a patient, clinicians should use assessments of impairment.

INTERVENTIONS - NEUROMUSCULAR ELECTRICAL STIMULATION

1A Neuromuscular electrical stimulation should be used for 4 to 8 weeks to improve muscle strengthening exercises in patients after ACL reconstruction to increase quadriceps muscle strength and enhance short-term functional outcomes.

of body structure and function, including measures of knee stability, knee joint movement coordination, thigh muscle strength, knee effusion, and knee joint range of motion.

1C Clinicians may use continuous passive motion in the immediate postoperative period to decrease postoperative pain after anterior cruciate ligament (ACL) reconstruction.

1C Clinicians may implement early weight bearing on hospital (within 1 week after surgery for patients after ACL reconstruction).

INTERVENTIONS - KNEE BRACING

1C Clinicians may use functional knee bracing in patients with ACL deficiency.

1D Clinicians should elicit and document patient preferences, in the decision to use functional knee bracing following ACL reconstruction, as evidence exists for and against its use.

1D Clinicians may use appropriate knee bracing for patients with acute anterior cruciate ligament (ACL) injuries, or postulated donor (FLX) or cultured ligament (ACL) injuries, or postulated donor (FLX) ACL reconstruction.

INTERVENTIONS - IMMEDIATE VERSUS DELAYED MOBILIZATION

1B Clinicians should use immediate mobilization (within 1 week) after ACL reconstruction to increase joint range of motion, reduce joint tissue adhesions, and reduce the risk of adverse responses of joint extension range of motion lock.

INTERVENTIONS - CRYOTHERAPY

1B Clinicians should use cryotherapy immediately after ACL reconstruction to reduce postoperative knee pain.

INTERVENTIONS - SUPERVISED REHABILITATION

1B Clinicians should use exercise as part of the clinical supervised rehabilitation program after ACL reconstruction and favorable and supervise the progression of a formal level exercise program, providing education to ensure independent performance.

INTERVENTIONS - THERAPEUTIC EXERCISES

1C Weight bearing exercises should be implemented within 4 to 6 weeks, 2 to 3 times per day to improve thigh muscle strength and functional performance after ACL reconstruction.

INTERVENTIONS - NEUROMUSCULAR RE-EDUCATION

1A Neuromuscular re-education training should be incorporated with muscle strengthening exercises in patients with knee stability and movement coordination impairments.

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Anterior Cruciate Ligament

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ACL



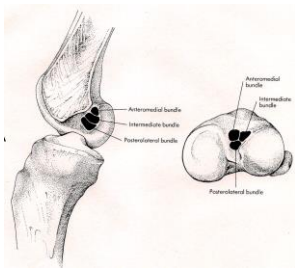
- 148714 reconstructions in 2013
- 70% non contact
- Account for more than \$500 million in healthcare costs per year
- Females 2.4 - 9.7x



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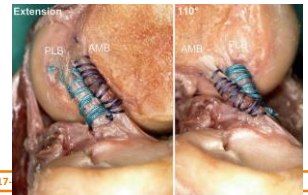
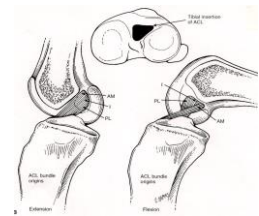
Anatomy

- Originates at posteromedial corner of the medial side of the lateral femoral condyle, attaches in a fossa anterolateral to the tibial spine
- Function:
 - Limits anterior tibial translation (85% at 30/90 degrees)
 - Secondary limitation of tibial IR, varus/valgus
 - Ultimate strength of a native ACL is ~2000N



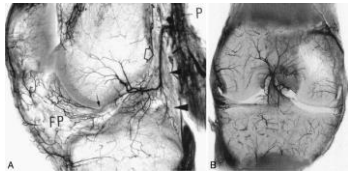
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- **Anteromedial bundle**
 - Tight throughout flexion
 - Anterior instability
 - Smaller
- **Posterolateral bundle**
 - Tight in extension
 - Greatest restraint to anterior translation from ext to 20deg flexion
 - Rotary instability
 - Larger
- **Both**
 - Secondary restraint to varus/valgus/tibial IR
 - Primary restraint to valgus force when MCL unable



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- Innervation:
 - Posterior articular branches of the tibial nerve
- Vascularization
 - Branches of the middle genicular artery
 - Infrapatellar Fat pad
 - Synovium



ACL

- Injury Mechanism:
 - Acceleration/deceleration at full extension or slight flexion (Excess Quad, Decr HS activation); coupled with tibial rotation
 - CKC IR/Valgus without HS co contraction
 - Medial tibial rotation
 - ACL winds around PCL
 - Lateral tibial rotation
 - ACL stretches over lateral condyle



A Systematic Summary of Systematic Reviews on the Topic of the Anterior Cruciate Ligament

Michael J. Anderson,* MD, William M. Browning III,* DO, MS, Christopher E. Urband,* MD, Melissa A. Kluczynski,* MS, and Leslie J. Bisson,*[†] MD

Purpose: To quantify the number of systematic reviews and meta-analyses published on the ACL in the past decade and to provide an overall summary of this literature.

Results: A total of 1031 articles were found, of which 240 met the inclusion criteria. Included articles were summarized and divided into 17 topics: anatomy, epidemiology, prevention, associated injuries, diagnosis, operative versus nonoperative management, graft choice, surgical technique, fixation methods, computer-assisted surgery, platelet-rich plasma, rehabilitation, return to play, outcomes assessment, arthritis, complications, and miscellaneous.

Rehab Before ACL Reconstruction?

Should patients reach certain knee function benchmarks before anterior cruciate ligament reconstruction? Does intense 'prehabilitation' before anterior cruciate ligament reconstruction influence outcome and return to sports?

M Hägglund,¹ M Waldén,² R Thomeé³

- 6 week prehabilitation program prior to ACLR resulted in significantly increased KOOS scores and increased hop tests which remained 12 weeks after surgery compared to a control group

How does a combined preoperative and postoperative rehabilitation programme influence the outcome of ACL reconstruction 2 years after surgery? A comparison between patients in the Delaware-Oslo ACL Cohort and the Norwegian National Knee Ligament Registry

H Grindem,¹ L P Granan,^{2,3,4} M A Risberg,^{1,5} L Engebretsen,^{3,6}
L Snyder-Mackler,⁷ I Eitzen⁵ Grindem H, et al. *Br J Sports Med* 2014;0:1-6. doi:10.1136/bjsports-2014-093891

Conclusions Patients in a prospective cohort who underwent progressive preoperative and postoperative rehabilitation at a sports medicine clinic showed superior patient-reported outcomes both preoperatively and 2 years postoperatively compared to patients in the NKLR who received usual care.



The effectiveness of pre-operative exercise physiotherapy rehabilitation on the outcomes of treatment following anterior cruciate ligament injury: A systematic review

Clinical Rehabilitation
1-11
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sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0269215516628617

Shady Alshewaiher^{1,2}, Gillian Yeowell¹ and Francis Fatoye¹

Results: A total of 500 studies were identified, of which eight studies met the inclusion criteria and were included in the present review. The average Physiotherapy Evidence Database score for the studies included was 5.8, which reflects an overall moderate methodological quality.

The eight studies investigated a total of 451 subjects of which 71% (n=319) were males. The age of the participants in the eight studies ranged from 15 to 57 years. The duration of the intervention in the studies ranged from 3 to 24 weeks. This review found that pre-operative physiotherapy rehabilitation is effective for improving the outcomes of treatment following anterior cruciate ligament injury, including increasing knee-related function and improving muscle strength. However, whilst there was a significant improvement in quality of life from baseline following intervention, no significant difference in quality of life was found between the control and intervention groups.

Conclusions: There is evidence to suggest that pre-operative physiotherapy rehabilitation is beneficial to patients with anterior cruciate ligament injury.

Double-Bundle Versus Single-Bundle Anterior Cruciate Ligament Reconstruction

A Prospective Randomized Study With 5-Year Results

Piia Suomalainen,¹ MD, Timo Järvelä,¹ MD, PhD, Antti Paakkala,¹ MD, PhD,
Pekka Kannus,² MD, PhD, and Markku Järvinen,¹ MD, PhD
Investigation performed at Tampere University Hospital (TAYS), Tampere, Finland

Results: Preoperatively, there were no differences between the groups. Eleven patients (7 in the SBB group, 3 in the SBM group, and 1 in the DB group) had a graft failure during the follow-up and went on to ACL revision surgery ($P < .043$). Of the remaining 79 patients, a 5-year follow-up was performed for 65 patients (20 in the DB group, 21 in the SBB group, and 24 in the SBM group) who had their grafts intact. At 5 years, there was no statistically significant difference in the pivot-shift or KT-1000 arthrometer tests. In the DB group, 20% of the patients had OA in the medial femorotibial compartment and 10% in the lateral compartment, while the corresponding figures were 33% and 18% in the single-bundle groups, again an insignificant finding. Further, no significant group differences were found in the knee scores.

Conclusion: The double-bundle surgery resulted in significantly fewer graft failures and subsequent revision ACL surgery than the single-bundle surgeries during the 5-year follow-up. Knee stability and OA rates were similar at 5 years. In view of the size of the groups, some caution should be exercised when interpreting the lack of difference in the secondary outcomes.

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Clinical outcomes of double- vs single-bundle anterior cruciate ligament reconstruction: A systematic review of randomized control trials

J. Kongtharvongsul¹, J. Attia², S. Thamakason³, C. Kijkanasathian⁴, P. Woratanarat⁴, A. Thakkinstant¹

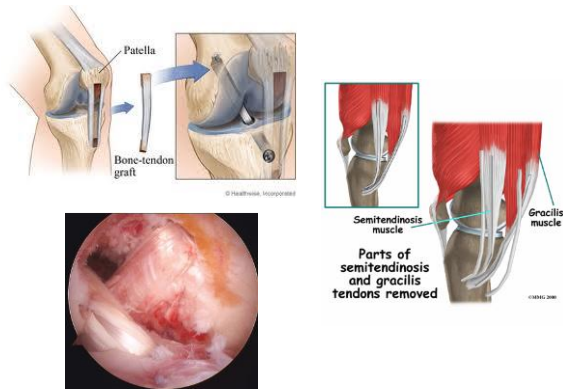
Clinical outcomes of anterior cruciate ligament (ACL) reconstruction with double-bundle and single-bundle techniques are still controversial. We therefore performed a systematic review to compare postoperative outcomes between the two techniques. Randomized control trials comparing the outcomes between the two techniques were identified from Medline and EMBASE since inception to April 27, 2011. Data were independently extracted by two reviewers. Thirteen of 318 studies were eligible; 9, 11, 7, and 8 studies were pooled for rotation, translation, function, and complication outcomes, respectively. The double-bundle technique was approximately four times (95% CI: 2.65, 11.99) and two times (95% CI: 1.16, 5.21)

more likely to show a normal pivot shift) and normal International Knee Documentation Committee (IKDC) grading compared with the single-bundle technique. However, there were nonsignificant differences in KT grading (OR = 1.66, 95% CI: 0.77, 3.82), IKDC score (0.29, 95% CI: -1.17, 1.75), Lysholm knee score (-0.87, 95% CI: -2.66, 0.93), Tegner activity score (0.37, 95% CI: -0.05, 0.79), and complications (OR = 1.11, 95% CI: 0.48, 2.57). Heterogeneity was present in some outcomes but there was no evidence of publication bias for any outcome. The double-bundle may be better than the single-bundle ACL reconstruction technique in rotational stability but not for function, translation, and complications.

Scand J Med Sci Sports 2012; 42: 1111-1116
doi: 10.1111/j.1600-8089.2011.01490.x

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MEDICINE & SCIENCE
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Quality of Life and Clinical Outcome Comparison of Semitendinosus and Gracilis Tendon Versus Patellar Tendon Autografts for Anterior Cruciate Ligament Reconstruction

An 11-Year Follow-up of a Randomized Controlled Trial

Matjaz Sajovic,¹ MD, PhD, Andrej Strahovnik,¹ MD, Mojca Z. Demovsek,¹ MD, PhD, and Katja Skaza,² PT
Investigation performed at General Hospital Celje, Celje, Slovenia

Results: At the 11-year follow-up, no statistically significant differences were seen with respect to the Lysholm score and Short Form-36, KT-1000 arthrometer laxity testing, anterior knee pain, single-legged hop test, or International Knee Documentation Committee (IKDC) classification results. Positive pivot-shift test (1+) was significantly more frequent in the PT group ($P = .036$). Twenty-two patients (81%) in the STG group and 16 patients (72%) in the PT group were still at their preinjury level of activity. Graft rupture occurred in 2 patients from the STG group (9%) and in 4 patients from the PT (12%). Grade B and C abnormal radiographic findings were seen in 84% (21 of 25) of patients in the PT group and in 63% (17 of 27) of patients in the STG group ($P = .008$).

Conclusion: Both hamstring and patellar tendon autografts provided good subjective outcomes and objective stability at 11 years. Positive pivot-shift test (1+) was significantly more frequent in the PT group. No significant differences in the rate of graft failure were identified. Patients with patellar tendon graft had a greater prevalence of osteoarthritis at 11 years after surgery.

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The American Journal of Sports Medicine, Vol. 39, No. 10
DOI: 10.1177/0963685411411702
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Reconstruction of the Anterior Cruciate Ligament: Meta-analysis of Patellar Tendon Versus Hamstring Tendon Autograft

John P. Goldblatt, M.D., Sean E. Fitzsimmons, M.D., Ethan Balk, M.D., M.P.H., and John C. Richmond, M.D.

Conclusions: The data presented in this meta-analysis show that the incidence of instability is not significantly different between the BPTB and HT grafts. However, BPTB was more likely to result in reconstructions with normal Lachman, normal pivot-shift, KT-1000 manual-maximum side-to-side difference <3 mm, and fewer results with significant flexion loss. In contrast, HT grafts had a reduced incidence of patellofemoral crepitance, kneeling pain, and extension loss. The choice of graft by the patient and surgeon must be individualized, and the results of this meta-analysis can aid in the decision by clarifying the risks and benefits of each surgical approach. **Level of Evidence:** Level I. **Key Words:**

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 21, No 7 (July), 2005; pp 791-803

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Autograft Versus Allograft Anterior Cruciate Ligament Reconstruction

A Prospective, Randomized Clinical Study With a Minimum 10-Year Follow-up

The American Journal of Sports Medicine, Vol. 30, No. 3
DOI: 10.1177/0363546510396400
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Craig R. Bottoni,¹ MD, Eric L. Smith,¹ MD, CPT James Shaha,¹ MD, Steven S. Shaha,⁵ PhD, Sarah G. Raybin,¹ BA, John M. Tokish,¹ MD, and CDR(Ret) Douglas J. Rowles,¹ MD

Conclusion: At a minimum of 10 years after ACL reconstruction in a young athletic population, over 80% of all grafts were intact and had maintained stability. However, those patients who had an allograft failed at a rate over 3 times higher than those with an autograft.

A systematic review of randomized controlled clinical trials comparing hamstring autografts versus bone-patellar tendon-bone autografts for the reconstruction of the anterior cruciate ligament

Shuzhen Li · Yueping Chen · Zonghan Lin · Wei Cui · Jingmin Zhao · Wei Su

Results: Nine RCTs (738 patients) met the inclusion criteria. The combined results of the meta-analysis indicated there was a significantly lower rate of negative Pivot test [relative risk (RR) 0.87, 95% confidence intervals (CI) 0.79–0.96, $P = 0.004$], anterior knee pain (RR 0.66, 95% CI 0.45–0.96, $P = 0.03$) and of kneeling pain (RR 0.49, 95% CI 0.27–0.91, $P = 0.02$) in the HT group than in the BPTB group.

Conclusions: ACL reconstruction with HT autografts or BPTB autografts achieved similar postoperative effects in terms of restoring knee joint function. HT autografts were inferior to BPTB autografts for restoring knee joint stability, but were associated with fewer postoperative complications.

Arch Orthop Trauma Surg (2012) 132:1287–1297
DOI 10.1007/s00402-012-1532-5

ARTHROSCOPY AND SPORTS MEDICINE



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- The healing process
 - It's a dead piece of tissue!
 - Graft needs to be re-vascularized
 - "Ligamentization" occurs
 - Vascular synovial layer wraps around graft in 4-6 weeks
- Autologous ACL grafts don't transition through necrotic stage
- Weakest link fixation 4-6 weeks
- Soft tissue graft to bone: 12 weeks
- Bone autograft to bone: 8 weeks
- Complete re-vascularization of the graft takes ~20 weeks
- Remodeling occurs:
 - By one year histological and biochemical properties of ACLR ≈ native ACL



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Healing Rate of Tissues

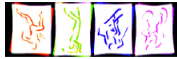
- Times affected by age, comorbidities, etc

Table 4. Healing Rates of Tissues.*

	0-3 days	4-14 days	3-4 weeks	5-7 weeks	2-3 months	3-6 months	6 months -1 year	Up to 2 years
Tendon								
• Tendinitis			←	→				
• Lacerations			←	→				
Muscle								
• Exercise-induced	←	→						
• Grade I	←	→						
• Grade II	←	→						
• Grade III	←	→						
Ligament								
• Grade I	←	→						
• Grade II	←	→						
• Grade III	←	→						
Ligament Graft ^{††}					←	→		
Bone								
Articular Cartilage Repair ^{†††}								

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Prevention



The Santa Monica Sports Medicine Research Foundation
The PEP Program: Prevent injury and Enhance Performance

Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes

2-Year Follow-up

The American Journal of Sports Medicine, Vol. 33, No. 7

The Santa Monica Orthopaedic and Sports Medicine Research Foundation
The PEP Program: Prevent injury and Enhance Performance

<http://www.aclprevent.com/index.htm>

Effectiveness of a Neuromuscular and Proprioceptive Training Program in Preventing the Incidence of Anterior Cruciate Ligament Injuries in Female Athletes

2-Year Follow-up

Methods: In 2000, 1041 female subjects from 52 teams received a sports-specific training intervention in a prospective non-randomized trial. The control group consisted of the remaining 1905 female soccer players from 95 teams participating in the same league who were age and skill matched. In the 2001 season, 844 female athletes from 45 teams were enrolled in the study, with 1913 female athletes (from 112 teams) serving as the age- and skill-matched control. All subjects were female soccer players between the ages of 14 and 18 and participated in either their traditional warm-up or a sports-specific training intervention before athletic activity over a 2-year period. The intervention consisted of education, stretching, strengthening, plyometrics, and sports-specific agility drills designed to replace the traditional warm-up.

Results: During the 2000 season, there was an 88% decrease in anterior cruciate ligament injury in the enrolled subjects compared to the control group. In year 2, during the 2001 season, there was a 74% reduction in anterior cruciate ligament tears in the intervention group compared to the age- and skill-matched controls.

Preventing ACL Injuries in Team-Sport Athletes: A Systematic Review of Training Interventions

MARKO D. STOJANOVIC and SERGEJ M. OSTOJIC
Center for Health, Exercise and Sport Sciences, Belgrade, Serbia

...ing interventions have a preventive effect on ACLI. Collectively, the studies indicate there is moderate evidence to support the use of multifaceted training interventions, which consisted of stretching, proprioception, strength, plyometric and agility drills with additional verbal and/or visual feedback on proper landing technique to decrease the rate of ACLIs in team sport female athletes, while the paucity of data preclude any conclusions for male athletes.

Research in Sports Medicine, 20:223-238, 2012
Copyright © Taylor & Francis Group, LLC
ISSN: 1543-8627 print/1543-8635 online
DOI: 10.1080/15438627.2012.680988

Interventions Designed to Prevent Anterior Cruciate Ligament Injuries in Adolescents and Adults

The American Journal of Sports Medicine, Vol. 41, No. 8
DOI: 10.1177/0363546512458227
© 2013 The Author(s)

A Systematic Review and Meta-analysis

Joel J. Gagnier,^{1††} ND, MSc, PhD, Hal Morgenstern,¹ PhD, and Laura Chess,⁵ MPH
Investigation performed at the University of Michigan, Ann Arbor, Michigan

Results: Eight cohort (observational) studies and 6 randomized trials were included, involving a total of approximately 27,000 participants. The random-effects meta-analysis yielded a pooled rate-ratio estimate of 0.485 (95% confidence interval [CI], 0.299-0.788; $P = .003$), indicating a lower ACL rate in the intervention groups, but there was appreciable heterogeneity of the estimated effect across studies ($I^2 = 64\%$; $P = .001$). In the meta-regressions, the estimated effect was stronger for studies that were not randomized, performed in the United States, conducted in soccer players, had a longer duration of follow-up (more than 1 season), and had more hours of training per week in the intervention group, better compliance, and no dropouts. Nevertheless, residual heterogeneity was still observed within subgroups of those variables ($I^2 > 50\%$; $P < .10$).

Conclusion: The authors found that various types of neuromuscular and educational interventions appear to reduce the incidence rate of ACL injuries by approximately 50%, but the estimated effect varied appreciably among studies and was not able to explain most of that variability.

Clinical Relevance: Neuromuscular and educational interventions appear to reduce the incidence rate of ACL injuries by approximately 50%.

Prevention and Screening Programs for Anterior Cruciate Ligament Injuries in Young Athletes

A Cost-Effectiveness Analysis

Eric Swart, MD, Lauren Redler, MD, Peter D. Fabricant, MD, MPH, Bert R. Mandelbaum, MD, Christopher S. Ahmad, MD, and Y. Claire Wang, MD, ScD

J Bone Joint Surg Am. 2014;96:705-11

Results: Universal neuromuscular training of all athletes was the dominant strategy, with better outcomes and lower costs compared with screening. On average, the implementation of a universal training program would save \$100 per player per season, and would reduce the incidence of ACL injury from 3% to 1.1% per season. Screening was not cost-effective within the range of reported sensitivity and specificity values.

Degenerative Changes in the Knee 2 Years After Anterior Cruciate Ligament Rupture and Related Risk Factors

A Prospective Observational Follow-up Study

Belle L. van Meer,^{1††} MD, PhD, Edwin H.G. Oei,⁵ MD, PhD, Duncan E. Meuffels,¹ MD, PhD, Ewoud R.A. van Arkel,¹ MD, PhD, Jan A.N. Verhaar,¹ MD, PhD, Sita M.A. Bierma-Zeinstra,^{1*} PhD, and Max Reijnen,¹ PhD

Results: The median time between MRI at baseline and MRI at 2-year follow-up was 25.9 months (interquartile range, 24.7-26.9 months). Progression of cartilage defects in the medial and lateral tibiofemoral compartments was present in 12% and 27% of patients, and progression of osteophytes in tibiofemoral and patellofemoral compartments was present in 10% and 8% of patients, respectively. The following determinants were positively significantly associated with early degenerative changes: male sex (odds ratio [OR], 4.43; 95% CI, 1.43-13.66; $P = .010$), cartilage defect in the medial tibiofemoral compartment at baseline (OR, 3.66; 95% CI, 1.04-12.95; $P = .044$), presence of bone marrow lesions in the medial tibiofemoral compartment 1 year after trauma (OR, 5.19; 95% CI, 1.56-17.25; $P = .007$), joint effusion 1 year after trauma (OR, 4.19; 95% CI, 1.05-16.72; $P = .042$), and presence of meniscal tears (OR, 6.37; 95% CI, 1.94-20.88; $P = .002$). When the patients were categorized into 3 treatment groups (nonoperative, reconstruction <6 months after ACL rupture, and reconstruction ≥6 months after ACL rupture), there was no significant relationship between the treatment options and the development of early degenerative changes.

Conclusion: Two years after ACL rupture, early degenerative changes were assessed on MRI. Concomitant medial cartilage defect and meniscal injury, male sex, persistent bone marrow lesions in the medial tibiofemoral compartment, and joint effusion are risk factors for degenerative changes.

Increased Risk of Osteoarthritis After Anterior Cruciate Ligament Reconstruction

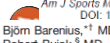
A 14-Year Follow-up Study of a Randomized Controlled Trial

- Investigated 14 years after ACL Repair
- Control was contralateral healthy knee
- Risk factors investigated for OA:
 - Weight
 - Other injuries
 - Sex
 - Age
 - Time between injury and repair
 - Graft type
- Graft type and time between injury and repair were not factors
- Meniscal resection was a significant risk factor
- **3 fold increase in OA in surgical knee vs control**
 - Mostly medial compartment



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Björn Bärenius,^{1*} MD, PhD, Sari Ponzer,¹ MD, PhD, Adel Shalabi,¹ MD, PhD, Robert Bujak,⁵ MD, PhD, Louise Norlén,¹ MD, and Karl Eriksson,¹ MD, PhD

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Which determinants predict tibiofemoral and patellofemoral osteoarthritis after anterior cruciate ligament injury? A systematic review

Belle L van Meer,¹ Duncan E Meuffels,¹ Wilbert A van Eijsden,¹ Jan A N Verhaar,¹ Sita M A Bierma-Zeinstra,^{1,2} Max Reijnen¹ van Meer B, et al. *Br J Sports Med* 2015;0:1-11. doi:10.1136/bjsports-2013-093258

Conclusions Medial meniscal injury/menisectomy after ACL rupture increased the risk of OA development. In contrast, it seems that lateral meniscal injury/menisectomy has no relationship with OA development. Our results suggest that time between injury and reconstruction does not influence patellofemoral and tibiofemoral OA development. Many determinants showed conflicting and limited evidence and no determinant showed strong evidence.

Is Anterior Cruciate Ligament Reconstruction Effective in Preventing Secondary Meniscal Tears and Osteoarthritis?

Thomas L. Sanders,^{1†} MD, Hilal Maradit Kremers,^{1†} MD, MSc, Andrew J. Bryan,¹ MD, Kristin M. Fruth,¹ BS, Dirk R. Larson,¹ MS, Ayooosh Pareek,¹ BS, Bruce A. Levy,¹ MD, Michael J. Stuart,¹ MD, Diane L. Dahm,¹ MD, and Aaron J. Krych,¹ MD
The American Journal of Sports Medicine, Vol. 44, No. 7
DOI: 10.1177/0363546516634325
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Conclusion: Patients treated with ACLR have a significantly lower risk of secondary meniscal tears, symptomatic arthritis, and TKA when compared with patients treated nonoperatively after ACL tears. Similarly, early ACLR significantly reduces the risk of subsequent meniscal tears and arthritis compared with delayed ACLR.



REHABILITATION

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INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION

A Neuromuscular electrical stimulation should be used for 6 to 8 weeks to augment muscle strengthening exercises in patients after ACL reconstruction to increase quadriceps muscle strength and enhance short-term functional outcomes.

INTERVENTIONS – NEUROMUSCULAR RE-EDUCATION

A Neuromuscular re-education training should be incorporated with muscle strengthening exercises in patients with knee stability and movement coordination impairments.

INTERVENTIONS – THERAPEUTIC EXERCISES

A Weight-bearing and non-weight-bearing concentric and eccentric exercises should be implemented within 4 to 6 weeks, 2 to 3 times per week for 6 to 10 months, to increase thigh muscle strength and functional performance after ACL reconstruction.

KYUNG-MIN KIM, MS, ATC¹ • TED CROW, PT, OCS² • JAY HERTEL, PhD, ATC³ • SUSAN SALIBA, PT, PhD, ATC⁴
J Orthop Sports Phys Ther 2010;40(7):383-391.

Effects of Neuromuscular Electrical Stimulation After Anterior Cruciate Ligament Reconstruction on Quadriceps Strength, Function, and Patient-Oriented Outcomes: A Systematic Review

CONCLUSION: NMES combined with exercise may be more effective in improving quadriceps strength than exercise alone, whereas its effect on functional performance and patient-oriented outcomes is inconclusive. Inconsistencies were noted in the NMES parameters and application of NMES.

Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus

Nicky van Melick,^{1,2} Robert E H van Cingel,^{3,4} Frans Brooijmans,⁵ Camille Neeter,⁶ Tony van Tienen,⁷ Wim Hulleaie,⁸ Maria W G Nijhuis-van der Sanden¹
Br J Sports Med 2016;0:1-13. doi:10.1136/bjsports-2015-095898

Summary Ninety studies were included as the basis for the evidence statement. Rehabilitation after ACL injury should include a prehabilitation phase and 3 criterion-based postoperative phases: (1) impairment-based, (2) sport-specific training and (3) return to play. A battery of strength and hop tests, quality of movement and psychological tests should be used to guide progression from one rehabilitation stage to the next. Postoperative rehabilitation should continue for 9–12 months. To assess readiness to return to play and the risk for reinjury, a test battery, including strength tests, hop tests and measurement of movement quality, should be used.

Rehabilitation Principles of the Anterior Cruciate Ligament Reconstructed Knee Twelve Steps for Successful Progression and Return to Play

Clin Sports Med 36 (2017) 189–232
<http://dx.doi.org/10.1016/j.csm.2016.08.012>
 Kevin E. Wilk, PT, DPT^{1,2,3,*}, Christopher A. Arrigo, MS, PT, ATC⁴
 0278-5919/17/© 2016 Elsevier Inc. All rights reserved.

- Box 1**
Twelve steps critical to successful anterior cruciate ligament rehabilitation
1. Preparation of both the patient and their knee for surgery
 2. Restore full passive knee extension
 3. Reduce postoperative inflammation
 4. Gradual restoration of full knee flexion
 5. Restore complete patellar mobility
 6. Individualize and adjust the rehabilitation program based on the status of the knee
 7. Reestablish quadriceps activation
 8. Restoration of dynamic functional stability of the knee complex
 9. Knee stability and dynamic control must be provided from both above and below
 10. Protect the knee both now and later
 11. Objective return to running
 12. Objective progressing beyond running and back to sport

- Box 2**
Rehabilitation phases, program goals and criteria for progression after anterior cruciate ligament reconstruction
1. Preoperative phase
 - a. Goals: Diminish inflammation, swelling and pain
 - i. Restore normal ROM (especially knee extension)
 - ii. Restore voluntary muscle activation
 - iii. Provide patient education to prepare for surgery
 2. Immediate postoperative phase (days 1–7)
 - a. Goals: Restore full passive knee extension
 - i. Diminish joint swelling and pain
 - ii. Restore patellar mobility
 - iii. Gradually improve knee flexion
 - iv. Reestablish quadriceps control
 - v. Restore independent ambulation
 - b. Criteria to progress to early rehabilitation phase
 - i. Quadriceps control (ability to perform good quadriceps set and straight leg raises)
 - ii. Full passive knee extension
 - iii. PROM: 0° to 90°
 - iv. Good patellar mobility
 - v. Minimal joint effusion
 - vi. Independent ambulation
 3. Early rehabilitation phase (weeks 2–6)
 - a. Goals: maintain full passive knee extension (≥0 to 5–7° hyperextension)
 - i. Gradually increase knee flexion
 - ii. Diminish remaining swelling and pain
 - iii. Improve muscle control and activation
 - iv. Restore proprioception/neuromuscular control
 - v. Normalize patellar mobility
 - b. Criteria to progress to strengthening/neuromuscular control phase
 - i. Active ROM (0° to 115°)
 - ii. Quadriceps strength 60% greater than the contralateral side (isometric test at 60° of knee flexion)
 - iii. Unchanged KT test bilateral values (≤1)
 - iv. Minimal to no knee joint effusion
 - v. No joint line or patellofemoral pain
 4. Progressive strengthening/neuromuscular control phase (Weeks 4–10)
 - a. Goals: restore full knee ROM (0°–125°)
 - i. Improve lower extremity strength
 - ii. Enhance proprioception, balance and neuromuscular control
 - iii. Improve muscular endurance
 - iv. Restore limb confidence and function
 - b. Criteria to progress to advanced activity phase
 - i. ABROM 0° to 125° or greater
 - ii. Quadriceps strength 75% of contralateral side
 - iii. Knee extension flexor:anterior ratio 70% to 75%
 - iv. No change in KT value (comparable with contralateral side, within 2 mm)
 - v. No pain or effusion
 - vi. Satisfactory clinical examination
 - vii. Satisfactory isokinetic test (values at 180°/0)
 1. Quadriceps bilateral comparison 75%
 2. Hamstring strength equal bilaterally
 3. Quadriceps peak torque/body weight ratios
 - a. 65% males
 - b. 55% females
 4. Single leg hop test 80% of contralateral leg
 5. Subjective knee scoring (modified Noyes system) 80 points or better
 - c. Goals: normalize lower extremity strength
 - i. Enhance muscular power and endurance
 - ii. Improve neuromuscular control
 - iii. Perform selected sport-specific drills
 - iv. Criteria to enter return to activity phase
 - i. Full ROM
 - ii. Unchanged KT test (within 2.5 mm of opposite side)
 - iii. Isokinetic test that fulfills criteria
 1. Quadriceps bilateral comparison 80% or greater
 2. Hamstring bilateral comparison 110% or greater
 3. Quadriceps torque/body weight ratio 55% or greater
 4. Hamstring/quadriceps ratio 70% or greater
 - iv. Proprioception test 100% of contralateral leg
 - i. Functional test 85% or greater of contralateral side
 - ii. Satisfactory clinical examination
 - iii. Subjective knee scoring (modified Noyes system) 90 points or better
 - d. Return to activity phase (Weeks 16–22)
 - a. Goals: gradual return to full unrestricted sports
 - b. Achieve maximal strength and endurance
 - c. Normalize neuromuscular control
 - d. Progress skill training

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LONNIE PALGOS, MD • JAMES R. ANDREWS, MD

Anterior Cruciate Ligament Strain and Tensile Forces for Weight-Bearing and Non-Weight-Bearing Exercises: A Guide to Exercise Selection

- Seated Knee Extension
 - Peak strain 3.2%-4.4% occurring at 10-30deg of knee flexion
 - Increases ~1% with 10lb weight
 - Increases 2x if weight placed at ankle vs prox tibia
- Seated Knee Flexion
 - No strain
- Single or Double Knee Squats
 - Minimal or no strain
 - No change with weight
 - If squat on toes is over 3x more loading through ACL
 - With trunk flexion of 30-40deg decreased load on ACL vs upright posture

MARCH 2012 | VOLUME 42 | NUMBER 3 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY



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- Forward/Side Lunges
 - ACL loading is minimal
- Leg Press
 - Minimal to no loading
 - No change with increased weight or different foot positions (high or low/wide or narrow)
- Bicycling
 - Peak strain 1.2%-2.1%
 - Lachman produced 3-3.5% strain
- Plyometric
 - 250N force with double leg jump from 60cm platform
 - Similar to load from seated knee extension



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- For both NWB and WB greater loading occurs at lower knee flexion angles (10-30deg)
 - Decreases from 30-60deg of knee flexion
 - None at above 60deg of knee flexion
- NWB exercises produce significantly more load on ACL than WB in same range of motion
- Use a forward trunk lean of 30-40deg with all WB therex
 - Increases HS recruitment to unload ACL
- Anterior knee translation beyond toes (>8cm) increases ACL load



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Recent Advances in the Rehabilitation of Anterior Cruciate Ligament Injuries

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 42 | NUMBER 3 | MARCH 2012 | 153

Goals:

- Full knee extension immediately
- Hyperextension returned equal to other side by week 2
- Restore Patellar Mobility
- Reduce post op inflammation
- Range of Motion
 - 0-90deg 5-7days post op
 - 0-100deg 7-10 days post op
- Reestablish voluntary quad control
- NMES
- Restore Neuromuscular control
- Proprioceptive training by week 2

By Graft Type:

- Less aggressive with soft tissue grafts
- Return to running, plyo and sports is slower
- Slower to aggressive activities for allograft vs autograft
- Increased healing time due to longer for fixation of soft tissue as it heals in bone tunnel



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Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY | VOLUME 42 | NUMBER 7 | JULY 2012 | 601

- With this protocol
 - 75% of patients had knee function w/i normal ranges at 6mo
 - 87% by 1 year
 - 40% of preoperative “non copers” passed return to sport by 6mo
 - 73% by 12mo
 - 90% or above on self report outcome questionnaires
 - 70% at 3mo
 - 92.5% at 6mo
 - Quad strength ~90% by 6mo post op
 - Typically 80% at 6 mo

- Running Progression
 - Starts at 8 weeks if
 - Quad strength 80% of uninvolved side
 - Trace effusion
 - Understanding of soreness rules
 - Full AROM
 - Normal gait

TABLE 4		RUNNING PROGRESSION*
Level	Treadmill	Track
Level 1	0.1 mi walk/0.1 mi jog, repeat 10 times	Jog straight/walk curves (2 mi)
Level 2	Alternate 0.1 mi walk/0.2 mi jog (2 mi)	Jog straight/jog 1 curve every other lap (2 mi)
Level 3	Alternate 0.1 mi walk/0.3 mi jog (2 mi)	Jog straight/jog 1 curve every lap (2 mi)
Level 4	Alternate 0.1 mi walk/0.4 mi jog (2 mi)	Jog 1.75 laps/walk curve (2 mi)
Level 5	Jog full 2 mi	Jog all laps (2 mi)
Level 6	Increase workout to 2.5 mi	Increase workout to 2.5 mi
Level 7	Increase workout to 3 mi	Increase workout to 3 mi
Level 8	Alternate between running/jogging every 0.25 mi	Increase speed on straight/jog curves

*Progress to next level when patient is able to perform activity for 2 mi without increased effusion or pain. Perform no more than 4 times in 1 week and no more frequently than every other day. Do not progress more than 2 levels in a 7-day period. Conversion: 1 mi = 1.6 km. Reprinted with permission from Yarn Manual, University of Delaware Physical Therapy Clinic.

TABLE 2		EFFUSION GRADING SCALE OF THE KNEE JOINT BASED ON THE STROKE TEST
Grade	Test Result	
Zero	No wave produced on downstroke	
Trace	Small wave on medial side with downstroke	
1+	Larger bulge on medial side with downstroke	
2+	Effusion spontaneously returns to medial side after upstroke (no downstroke necessary)	
3+	So much fluid that it is not possible to move the effusion out of the medial aspect of the knee	

Reproduced from Sturgill et al.¹⁰

TABLE 3		SORENESS RULES*
Criterion	Action	
Soreness during warm-up that continues	2 days off, drop down 1 level	
Soreness during warm-up that goes away	Stay at level that led to soreness	
Soreness during warm-up that goes away but redevelops during session	2 days off, drop down 1 level	
Soreness the day after lifting (not muscle soreness)	1 day off, do not advance program to the next level	
No soreness	Advance 1 level per week or as instructed by healthcare professional	

*Reprinted with permission from SAGE Publications: Fees M, Decker T, Snyder-Mackler L, Aze MJ. Upper extremity weight-training modifications for the injured athlete. A clinical perspective. Am J Sports Med. 2008;36(5):728. Copyright © 2008 SAGE Publications.

- More specific goals for each phase of rehab and specific return to sport guidelines
- Addition of guidelines for concomitant injuries
 - Ligamentous, meniscal or chondral



RETURN TO SPORT

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Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

Sue D. Barber-Westin, B.S., and Frank R. Noyes, M.D.

months' follow-up. **Results:** Of 716 studies identified, 264 met the inclusion criteria. Of these, 105 (40%) failed to provide any criteria for return to sports after ACL reconstruction. In 84 studies (32%) the amount of time postoperatively was the only criterion provided. In 40 studies (15%) the amount of time along with subjective criteria were given. Only 35 studies (13%) noted objective criteria required for return to athletics. These criteria included muscle strength or thigh circumference (28 studies), general knee examination (15 studies), single-leg hop tests (10 studies), Lachman rating (1 study), and validated questionnaires (1 study). **Conclusions:** The results of this systematic review show noteworthy problems and a lack of objective assessment before release to unrestricted sports activities. General recommendations are made for quantification of muscle strength, stability, neuromuscular control, and function in patients who desire to return to athletics after ACL reconstruction, with acknowledgment of the need for continued research in this area. **Level of Evidence:** Level IV, systematic review of Level I to IV studies.

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 27, No 12 (December), 2011; pp 1897-1705



JOSPT PERSPECTIVES FOR PATIENTS

Return to Sport When to Resume Full Activity After an ACL Surgery

John M. Smith, PhD, The University of Iowa, Iowa City, IA 52242-1527

A thorough surgery to fix a torn anterior cruciate ligament (ACL) is common, knowing when to be able to return to activities and sports after ACL reconstruction is not always clear. Following surgery, patients participate in a progressive rehabilitation program with the goal of restoring their activities and sports. As part of their rehabilitation, patients often fill out surveys, such as the International Knee Documentation Committee (IKDC) survey, that ask questions about how patients think they are recovering. It is not clear, though, how well these surveys really predict an athlete's readiness to get back to activities and sports. A study published in the December 2014 issue of JOSPT provides new insight and evidence-based tools to help answer this question.

NEW INSIGHTS
The researchers who conducted this study better understand what patients, starting in the weeks to 12 to 16 weeks, are and are not ready to do after ACL surgery. All patients completed the IKDC survey. The researchers also interviewed 100 patients (50 who were interviewed before surgery and 50 who were interviewed after surgery) to learn how well they perceived the strength and stability of their knee. These results were compared to their survey responses. The researchers found that 68% of athletes who were ready to do their sports were also able to do the hop test. Further, only 30% of athletes who were not ready to do their sports were able to do the hop test. The researchers found similar results in females.

PRACTICAL ADVICE
Athletes who score poorly on the IKDC survey were more likely to be unable to do the hop test. These athletes didn't seem to be ready to return to activities and sports. However, the athletes who were not ready to do their sports were able to do the hop test. Therefore, the IKDC survey cannot predict an athlete's readiness to return to sports. The researchers found that the athletes who were not ready to do their sports were also able to do the hop test. The researchers found that the athletes who were not ready to do their sports were also able to do the hop test. The researchers found that the athletes who were not ready to do their sports were also able to do the hop test.

STRENGTH AND FUNCTIONAL TESTS When a athlete returns to activities and sports after an ACL injury, surgery, and rehabilitation, objective measures, such as strength tests, and functional hop tests, can provide insight into athletes who are ready to get back to their activities and sports. The researchers found that athletes who were able to jump and hop successfully were able to do a hop test. In contrast, those who were unable to jump and hop successfully were unable to do a hop test. The researchers found that the athletes who were able to jump and hop successfully were able to do a hop test. The researchers found that the athletes who were able to jump and hop successfully were able to do a hop test.

This Perspective article was written by a team of JOSPT Editorial Board and staff with Debra L. Taylor, PT, PhD, Editor, and Jennifer Hootman, MEd, Editor.

This JOSPT Perspective for Patients is based on an article by Joseph D. et al. "Is It Time to Stop Hop Test From ACL Reconstruction? A Retrospective Study of Hop Test." *Orthopaedic Sports Physical Therapy* 2014; 34(12): 1705-1710. DOI: 10.1016/j.jospt.2014.09.012

For more information, visit JOSPT Perspectives for Patients online at www.jospt.com

- JOSPT Patient Perspective – December 2014



Factors Used to Determine Return to Unrestricted Sports Activities After Anterior Cruciate Ligament Reconstruction

Sue D. Barber-Westin, B.S., and Frank R. Noyes, M.D.

- Recommendations:
 - Less than 10% deficit in strength of QS vs HS on isokinetic at 180 and 300deg/sec
 - Less than 15% deficit in symmetry on single leg hop testing
 - Single hop, triple hop, crossover hop, timed hop
 - Less than 3mm increased A-P tibial displacement on Lachman or arthrometer testing
 - Greater than 60% knee separation distance on video drop-jump test
 - No effusion
 - Normal ROM/patellar mobility
 - No or slight patellar crepitus
 - No pain or swelling with all activities



TABLE 5	RETURN-TO-SPORT CRITERIA*
	<ul style="list-style-type: none"> • Minimum 12 wk postoperative • 90% or greater on quadriceps index • 90% or greater on all hop tests • 90% or greater on KOS-ADL • 90% or greater on global rating score of knee function
	<p><i>Abbreviations:</i> KOS-ADL, Knee Outcome Survey-activities of daily living.</p> <p>*All criteria must be met prior to beginning a return-to-sport progression.</p>

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Current Concepts for Anterior Cruciate Ligament Reconstruction: A Criterion-Based Rehabilitation Progression

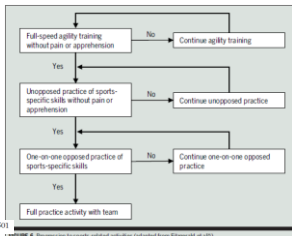


FIGURE 6. Progression to sports-related activities (adapted from Fitzgerald et al¹⁷).

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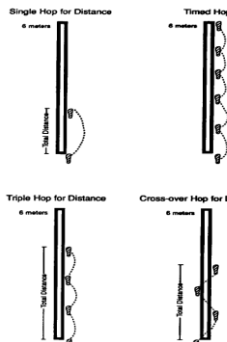


Figure 1. The courses for the four function tests.

Testing

- Patient performs 2 practice trials on each leg for each hop sequence
- Patient performs 2 timed or measured trials on each leg for each hop sequence
- Measured trials are averaged and compared (involved to uninvolved) for single, triple, and crossover hop
- Measured trials are averaged and compared (uninvolved to involved) for timed hop

Passing criteria for return to sport

- Greater than or equal to 90% on quadriceps MVIC, hop testing, KOS-ADL score, and global rating of knee function score



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Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: American Football

Mark Versteeg, Susan Fabiane, Russell Orr, Steve Smith
 J Orthop Sports Phys Ther 2012;42(4):337-344. doi:10.2519/jospt.2012.4031
 [Abstract] [Full Text] [Videos]

Suggestions From the Field for Return-to-Sport Rehabilitation Following Anterior Cruciate Ligament Reconstruction: Alpine Skiing

Dirk Kolopeter, Michael Hoff, Matt Myrnes
 J Orthop Sports Phys Ther 2012;42(4):313-325. doi:10.2519/jospt.2012.4024
 [Abstract] [Full Text] [Videos] [Slides]

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: Basketball

Eric Weles
 J Orthop Sports Phys Ther 2012;42(4):326-336. doi:10.2519/jospt.2012.4030
 [Abstract] [Full Text] [Videos]

Suggestions From the Field for Return to Sports Participation Following Anterior Cruciate Ligament Reconstruction: Soccer

Mario Szabo, Dave Hancock, Franco Impellizzeri
 J Orthop Sports Phys Ther 2012;42(4):304-312. doi:10.2519/jospt.2012.4005
 [Abstract] [Full Text] [Videos] [Slides]

The Challenge of Return to Sports for Patients Post-ACL Reconstruction

Guy G. Simoneau, Kevin E. Wik
 J Orthop Sports Phys Ther 2012;42(4):300-301. doi:10.2519/jospt.2012.0106

Likelihood of ACL graft rupture: not meeting six clinical discharge criteria before return to sport is associated with a four times greater risk of rupture

Polyvios Kyritsis,¹ Roald Bahr,^{1,2} Philippe Landreau,¹ Riadh Miladi,¹ Erik Witvrouw^{1,3}
 Br J Sports Med 2016;50:946-951. doi:10.1136/bjsports-2015-095908

Conclusions Athletes who did not meet the discharge criteria before returning to professional sport had a four times greater risk of sustaining an ACL graft rupture compared with those who met all six RTS criteria. In addition, hamstring to quadriceps strength ratio deficits were associated with an increased risk of an ACL graft rupture.



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Neuromuscular Training to Target Deficits Associated With Second Anterior Cruciate Ligament Injury

STEPHANIE DI STASI, PT, PhD, OCS[®] • GREGORY D. MYER, PhD, FACS[®], CSCS[®] • TIMOTHY E. HEWETT, PhD, FACS[®]
 JOURNAL OF ORTHOPAEDIC SPORTS PHYSICAL THERAPY | VOLUME 43 | NUMBER 11 | NOVEMBER 2013

Assessment Method	Impairments Assessed	Clinically Important Cutoff Criteria	Evidence for Clinical Applicability
High muscle dynamometry	Quadriceps and hamstrings side-to-side symmetry; hamstring:quadriceps ratio	90% or greater ²⁴	1. Athletes who underwent ACLR and had at least 90% quadriceps strength index (side-to-side symmetry) demonstrated functional performance similar to uninjured control subjects ²⁵ . 2. Female athletes who went on to sustain a primary ACL rupture had decreased hamstring:quadriceps ratios compared to male controls ⁸ .
Single-leg hop tests	Dynamic, sports-related knee function side-to-side symmetry	90% or greater ²⁶	1. Limb symmetry indices on single-leg hop for distance, triple hop for distance, and crossover hop for distance differed between controls and athletes who had ACLR ²⁶ . 2. Symmetry on the triple hop for distance was the most strongly correlated to self-reported function of the 4 hop tests ²⁶ .
Tuck jump	Trunk and lower extremity asymmetry and quality of mechanics	Perfect score of 80 points (no asymmetries or abnormalities) ²⁷	1. Feedback provided on tuck jump technique reduces knee abduction motion during the drop-vertical jump ²⁸ .
Drop-vertical jump	Sagittal and frontal plane knee mechanics	Greater than 60% normalized knee separation distance ²⁹	1. Sagittal and frontal plane knee motion during a drop-vertical jump is part of a clinical algorithm that accurately predicts high external knee abduction loads ²⁹ .
Patient-reported outcomes	Patient perception of function, symptoms, sport-related disability	90% or greater ³⁰	1. IKDC scores were lower in athletes who underwent ACLR compared to controls, and lowest in the athletes with strength asymmetries greater than 15% ³⁰ . 2. Use of self-reported outcomes is advised as part of a battery of tests to determine functional status following acute ACL injury ³¹ and readiness to return to sport following ACLR.

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; IKDC, International Knee Documentation Committee Subjective Knee Evaluation Form.

Exercise/Task	Key Muscles Targeted	Key Metrics/Elements Targeted	Direct Evidence for Targeted Effect	Indirect Evidence for Targeted Effect
Single-leg anterior progression	Gluteals; quadriceps and hamstrings	Sagittal plane trunk and LE joint motion; plyometric	1. Single-leg squat activated gluteus medius and maximus similarly and elicited greater gluteus maximus activation ³² .	1. Athletes with ACL deficiency shifted moments away from knee during hopping, and their center of mass was more anterior-ventral controls ³³ .
Single-leg lateral progression	Gluteals; trunk musculature; quadriceps and hamstrings	Frontal plane trunk and LE joint motion; unstable surface; plyometric	1. Single-leg squat activated gluteus medius and maximus similarly and elicited greater gluteus maximus activation ³² . 2. High hamstring:quadriceps co-activation ratios occurred with lateral hopping ³⁴ .	1. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls ³³ . 2. Healthy athletes with increased knee valgus demonstrated higher hip adductor, gluteocondylar, and tibial anterior activation ³⁵ . 3. Unstable surface shifted joint moments proximally ³⁶ .
Lunge progression	Gluteals; quadriceps and hamstrings	3-D trunk and LE joint motion; plyometric	1. Forward lunge elicited high hamstring:quadriceps coactivation ratios ³⁷ . 2. Lunge elicited greater than 75% vastus medialis muscle activity ³⁸ .	1. Quadriceps strength was significantly correlated with lateral sagittal plane knee movement ³³ and dynamic knee function in athletes following ACLR ^{39,40} .
Tuck jump progression	Gluteals; trunk musculature	Symmetry of LE movement; frontal plane trunk and LE joint motion; plyometric	Symmetry of LE movement; frontal plane trunk and LE joint motion; plyometric	None
Lateral jumping progression	Gluteals; quadriceps and hamstrings	3-D LE joint motion; plyometric	1. High hamstring:quadriceps coactivation ratios occurred with lateral hopping ³⁴ .	1. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls ³³ . 2. Increased lateral trunk motion increased external knee abduction moment ⁴¹ .
Lateral trunk progression	Trunk musculature	Frontal and transverse plane trunk motion	1. External oblique demonstrated high levels of muscle activity in sidelaying flexion exercises ⁴² .	1. Increased lateral trunk displacement with secured lower extremities predicted knee ligament injury ⁴³ . 2. Maximum lateral trunk displacement with secured lower extremities predicted ligament injury in females only ⁴⁴ .
Prow trunk stability	Gluteals; trunk musculature	Sagittal and transverse plane trunk motion	1. Prow bridge elicited high abdominal muscle activity ⁴⁵ . 2. Trunk extension combined with hip extension elicited trunk extensor activation up to 50% ⁴⁶ .	None

Exercise/Task	Key Muscles Targeted	Key Metrics/Elements Targeted	Direct Evidence for Targeted Effect	Indirect Evidence for Targeted Effect
Rowing trunk stability	Gluteals; trunk musculature	3-D trunk motion; unstable surface	None	1. Unstable surface shifted joint moments proximally ³⁶ . 2. Increased lateral trunk motion increased external knee abduction moment ⁴¹ . 3. Increased early lateral trunk displacement with secured lower extremities predicted knee ligament injury ⁴³ . 4. Maximum lateral trunk displacement with secured lower extremities predicted ligament injury in females only ⁴⁴ .
Push/row chain progression	Gluteals; trunk musculature; hamstrings	Transverse plane trunk and hip motion	1. Single-leg bridge elicited high gluteus medius, hamstrings, bicepsimus thoracis, and multifidus activity ⁴⁷ .	None
Single-leg dead lift progression	Gluteals; trunk musculature; hamstrings	3-D trunk and LE joint motion; unstable surface	1. Single-leg dead lift activated gluteus medius and maximus similarly and elicited greater gluteus maximus activation ³² . 2. High hamstring:quadriceps activation ratios with Romanian dead lift ⁴⁸ .	1. Unstable surface shifted joint moments proximally ³⁶ .
Lunge jump progression	Gluteals; trunk musculature; quadriceps and hamstrings	3-D trunk and LE joint motion; plyometric	1. Forward lunge elicited low hamstring:quadriceps coactivation ratios ³⁷ . 2. Large elicited greater than 75% vastus medialis muscle activity ³⁸ .	1. Long-axis neuromuscular training increased propulsive jumping forces, reduced joint velocities during landing phase, and early stabilization ⁴⁹ . 2. Long-axis neuromuscular training increased knee flexion, increased gluteal muscle efficiency, changed timing of frontal plane peak ⁵⁰ . 3. Athletes with ACL deficiency shifted moments away from knee during hopping versus controls ³³ . 4. Quadriceps strength was significantly correlated with external sagittal plane knee movement ³³ and dynamic knee function in athletes following ACLR ^{39,40} .

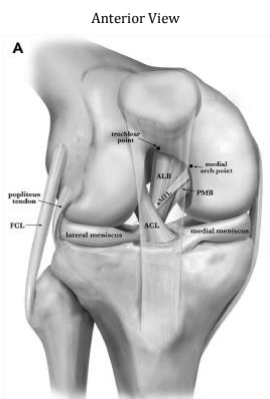


POSTERIOR CRUCIATE LIGAMENT

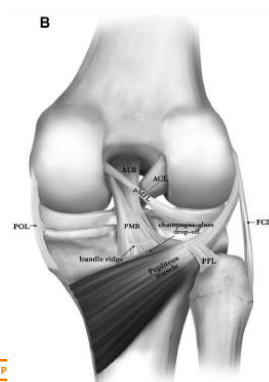
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Anatomy

- Lateral aspect of medial femoral condyle to posterior tibial spine
- Anterolateral bundle and Posteromedial bundle
 - Anterolateral
 - Larger (95%)
 - Tight in flexion
 - Posteromedial
 - Smaller (5%)
 - Tight in extension



Posterior View



Injury Mechanism

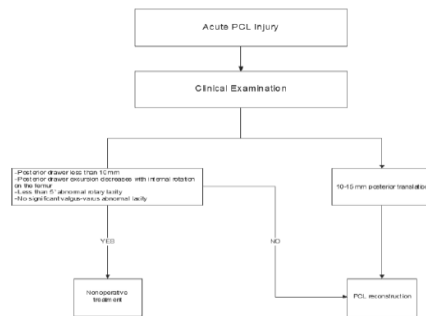
- Function: Limits....
 - Posterior Tibial translation (primary – 90%)
 - In full extension bears ~93% of posterior directed force
 - Most important at 70-90deg of flexion due to laxity of secondary restraints (MCL, popliteus, capsule)
 - Ext Rot tibia (secondary)
 - 90% multi lig injury

- MVA
 - “Dashboard injury”
- Contact sports
 - Fall on a bent knee with their foot plantar flexed. The tibia hits the ground first and it translates posteriorly.
 - Hyper flexion in external rotation





Evaluation and Treatment of Posterior Cruciate Ligament Injuries : Revisited
 William M. Wind, Jr, John A. Bergfeld and Richard D. Parker
Am J Sports Med 2004 32: 1785



Treatment

- Non Operative
 - Indicated for:
 - Grade I-II isolated tears
 - Non displaced grade II avulsion from tibia
 - Brace immobilization x2-4weeks
 - Focus on ROM, quad activation and limiting HS overactivity initially progressing to closed chain strengthening/proprioception/quad strength
 - Slow progression compared to ACL

Treatment

- Operative
 - Indicated for:
 - All grade III injuries; either isolated or with combined instability
 - Bony avulsion that requires ORIF
 - Some isolated grade II lesions in high demand athletes

TABLE 1. PCL Postoperative Rehabilitation Program

Postoperative Period	Program
Weeks 1 through 3	Non-weight-bearing with crutches; long leg brace locked in full extension.
Weeks 4 through 6	Non-weight-bearing with crutches continues until the end of postoperative week 6. The long leg brace is unlocked, and progressive range of motion begins during postoperative weeks 4 through 6.
Weeks 7 through 10	Progressive weight-bearing with crutches at 25% of body weight per week over a period of 4 weeks to full weight-bearing at the end of postoperative week 10.
Weeks 11 through 24	Progressive range of motion and strength training, avoiding resisted hamstring exercises.
Weeks 25 through 52	Continue strength and agility training. Return to sports or heavy labor when strength, range of motion, and proprioceptive skills are symmetric to the uninjured lower extremity.



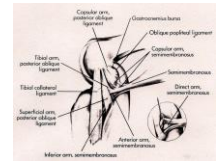
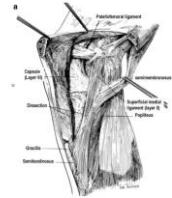
MEDIAL COLLATERAL LIGAMENT

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Anatomy

- Medial aspect femur (proximal-posterior to medial femoral epicondyle) courses distal and attaches anterior to posteriomedial tibial crest, distal to medial tibial plateau
- 3 tissue layers
 - Superficial
 - Deep
 - Posterior Oblique
- Multiple connections to joint capsule, med meniscus, muscle-tendon units



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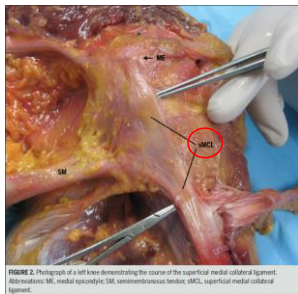


FIGURE 2. Photograph of a left knee demonstrating the course of the superficial medial collateral ligament. Abbreviations: ME, medial epicondyle; SM, semimembranosus tendon; SMCL, superficial medial collateral ligament.

Superficial

Anatomy

Deep

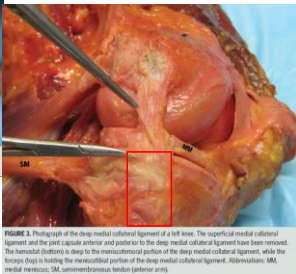


FIGURE 3. Photograph of the deep medial collateral ligament of a left knee. The superficial medial collateral ligament and the joint capsule anterior and posterior to the deep medial collateral ligament have been removed. The femoral condyles are deep to the noncondylar portion of the deep medial collateral ligament. While the forceps drag is holding the meniscotibial portion of the deep medial collateral ligament. Abbreviations: MM, medial meniscus; SM, semimembranosus tendon (anterior arm).

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Anatomy

Posterior Oblique

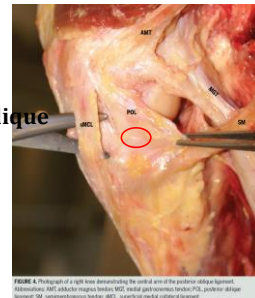


FIGURE 4. Photograph of a left knee demonstrating the medial aspect of the posterior oblique ligament. Abbreviations: AMT, anterior articular meniscus; PCL, posterior cruciate ligament; PCL, posterior cruciate ligament; SM, semimembranosus tendon; SMCL, superficial medial collateral ligament.

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MCL Function

- 57% Valgus stability at 5 degrees knee flexion
- 78% Valgus stability at 25 degrees knee flexion
 - Due to decreased contribution from posterior capsule



MCL

- Valgus blow
- CKC - plant/cut valgus stress
- 7.9% of all athletic injuries
 - Most common NFL/alpine skiing
 - Second in collegiate hockey, women's rugby
- Grade III injury ~80% concomitant lig injury
 - 95% of the time ACL



MCL

- Treatment guidelines
 - Grade I/II
 - Non operative
 - Rest/ice
 - Hinged brace
 - Early ROM - Strength/Proprioception
 - Early weightbearing
 - Avg. return to football 20 days (grade II)
 - 74% return to pre injury activity level at 3mo
- Grade III
 - Rx - controversial
 - Most treated non operatively
 - Indications for surgery
 - » Avulsion fx with bony fragment
 - » Laxity affecting sports performance/daily activities
 - » Consistently positive stress radiographs for MCL
 - ACL + MCL (standard of care reconstruct ACL, not MCL)

MCL Bracing

V The New Zealand Guideline Group⁵ 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





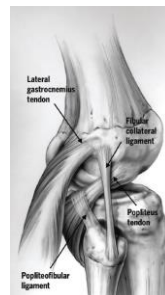
LATERAL COLLATERAL LIGAMENT

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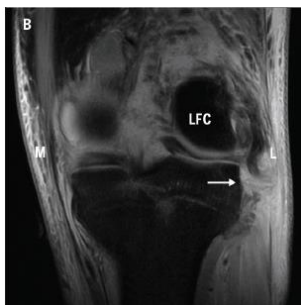
Anatomy

- Attaches equidistant from posterior and distal border of lateral femoral condyle and distally to superior and lateral facing V-shaped plateau on the fibular head
- Function
 - Resists varus force @ 0 and 30 degrees
 - 55% of varus load at 5deg
 - Posterior lateral capsule 13% ,ITB 5%, cruciate ligs the remaining amount
 - 69% of varus load at 25deg
 - Posterior structures on slack in flexion-preferred test
 - Secondary: limit ER of a flexed knee



LCL

- Injury Mechanism:
 - Least commonly injured knee ligament
 - Incidence of 4%
 - Usually with a soft tissue avulsion off prox femur or bony avulsion off fibular head
 - Typically with more extensive PLC injury



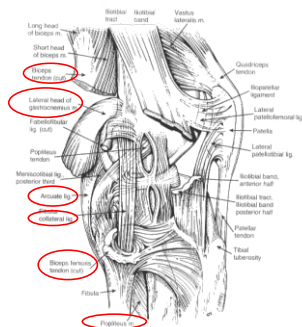
POSTEROLATERAL CORNER (PLC)

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Anatomy

- **Muscles:**
 - Popliteus
 - Lateral Head of Gastrocnemius
 - Short head of Biceps Femoris
- **Ligaments:**
 - Fibular Collateral Lig
 - Arcuate Ligament
- **Misc:**
 - Lateral Meniscus
 - Lateral Retinaculum



- One of the most common multi-ligament injuries
- Isolated injuries to PLC 1.6% of all ligament injuries
- Concomitant PLC and other ligament injury: 43-80%
 - Vehicular Trauma: 64%
 - Athletic Injury: 46%
- Commonly missed with failed ACL
- **Prevents:**
 - Primary:
 - Varus
 - Tibial ER
 - Secondary
 - Assists PCL with posterior tibial translation (30 degrees)
 - Hyperextension

PLC

- **Injury Mechanism:**
 - Blow to anteromedial aspect tibia near or at full extension
 - Forced hyperextension/varus
 - Valgus force on flexed knee
 - Severe tibial ER in flex or extension



Treatment

- Grade I and II
 - Good results non-operatively
- Grade III
 - Good results operatively if performed within 3 weeks of injury
- Better success operatively of acute vs chronic injuries

Non Operative Treatment

- Phase I
 - Edema management
 - QS activation
 - ROM return
- Phase II
 - Gait mechanics
 - Increase strength
 - QS, HS, GS, Popliteus, Hip, Lumbopelvic
- Phase III
 - Neuromuscular control
 - Control of varus and tibial ER at increased angles of knee flexion
- Phase IV
 - Sport specific training

Post Operative Treatment

- NWB x6weeks
 - Immobilizer locked out for 1-2 weeks
- ROM
 - 0-90 in 2 weeks
 - Full in 6weeks
- Full body squats permitted at 12weeks
- Until 4 months, no....
 - CKC therex at greater than 70deg knee flexion
 - Tibial ER
 - Resisted or repetitive HS in knee flexion



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PROTOCOL FOR REHABILITATION OF A POSTEROLATERAL KNEE RECONSTRUCTION

Procedure

The popliteus tendon, the popliteofibular ligament, and fibular collateral ligament are reconstructed.
This protocol can be combined with cruciate reconstruction protocols, adhering to all restrictions for each protocol.

Postoperative Restrictions:

1. Patient remains in the knee immobilizer in full knee extension at all times during the first 6 weeks postoperatively other than when working on knee range of motion (ROM) or performing quadriceps exercises.
2. Patient remains non-weight bearing for 6 weeks.
3. Patient to avoid tibial external rotation, and external rotation of the foot/ankle, especially in sitting for the first 4 months postoperatively.
4. Patient avoids open-chain hamstring exercises until 4 months postoperatively.

Postoperative Red Flags

Signs and symptoms of infection (excessive swelling, body temperature [fever] greater than 103°, increasing redness around the surgical incisions) call swelling or tenderness, lack of full knee extension, complaints of knee instability, complaints of catching or locking, and increased effusion following activity/therapy.

Phase 1

Weeks 1-2

1. Edema management: ice, compression, elevation.
2. Quadriceps sets and straight leg raises (SLRs) performed in the knee immobilizer. Quadriceps sets can be performed hourly up to 30 repetitions and SLR up to 30 repetitions 4 to 5 times per day.
3. Four times a day gentle passive and active assisted ROM exercises. Goal is 90° of knee flexion by the end of 2 weeks, and 0° of knee extension.
4. Core (lumbopelvic and hip) stabilization exercises in knee immobilizer that do not increase knee forces in varus, hyperextension, or tibial external rotation.

Weeks 3-6

1. Continue with passive and active assisted ROM exercises 4 to 6 times per day. Patient should achieve full extension at this time, and 120° of flexion.
2. Continue with quadriceps sets and SLRs.

Phase 2

Weeks 7-12

1. Start partial weight bearing using crutches. Goal is to ambulate full weight bearing without crutches within 2 weeks. Patient must be walking without a limp to discharge crutches. Discontinue knee immobilizer if able to perform SLR without a knee extension lag.
2. Initiate use of stationary exercise bike if 105° of knee flexion ROM is achieved. Working

on motion, beginning with 5 minutes every other day and increasing to 20 minutes daily based on the knee's response to increased activity. If soreness or effusion is evident reduce time or days utilizing the bike.

Weeks 13-36

At this time the patient should have a normal gait pattern, without the presence of a limp or Trendelenburg sign. The physician should be notified if patient is lacking 5° or more of extension or has less than 130° of flexion.

1. Leg press up to 25% of the patient's body weight to fatigue. Knee flexion allowed to a maximum of 70°.
2. Squat rack/kagat machine using weight up to 50%, body weight 10 repetitions, again not exceeding 90° of knee flexion. Slow progression to full body weight.
3. Closed kinetic chain exercise progression: double limb squatting, lunges, single limb squatting, etc. All exercises performed with less than 70° of knee flexion.
4. Daily biking or swimming, if swimming, no whiplash or flip turns.

Phase 3

Months 4-6 (Weeks 36-48)

Physical therapy goals: improve quadriceps strength and function, increase endurance, improve coordination, improve proprioception.

1. Walking program 20 to 30 minutes daily with a medium to brisk pace. Add 5 minutes per week.
2. Resistance can be added to bicycling as tolerated. Biking done 3 to 5 times per week for 20 minutes, and the lower activities should feel fatigued post biking.
3. Advanced closed kinetic chain exercise progression: addition of unstable surface, movement patterns, resistance, etc.
4. Return to run program once patient is able to perform 20 repetitions of involved knee extremely single limb squatting to greater than 60° of knee flexion with good control.
5. Plyometric progression: supported jumping, jumping, hopping, hopping, etc.

Month 7 and Beyond (Week 39)

1. Maintenance of home exercise program 3 to 5 times per week.
Note: Physician will give clearance for cutting and pivoting and sports simulation activities as appropriate. Physician clearance is based on favorable outcomes with imaging studies, clinical exam findings, and functional progression with therapy. The coordination of care between the surgeon and physical therapy staff is critical for a complete assessment of patient function and a complete recovery from the surgery.
Functional testing often performed at this time. A progressive return-to-play program is initiated if the limb symmetry index is greater than 85% with functional testing and satisfactory vision stress radiographs.



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MENISCUS

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DAVID S. LOGERSTEDT, PT, MA • LYNN SNYDER-MACKLER, PT, SCD • RICHARD C. RITTER, DPT • MICHAEL J. AXE, MD

Knee Pain and Mobility Impairments: Meniscal and Articular Cartilage Lesions

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

J Orthop Sports Phys Ther. 2010;40(6):A1-A35. doi:10.2519/jospt.2010.0304

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CLINICAL GUIDELINES

Summary of Recommendations

- 1.C. CLINICAL COURSE**
Knee pain and mobility impairments associated with meniscal and articular cartilage tears can be the result of a contact or noncontact incident, which can result in damage to 1 or more structures. Clinicians should assess for impairments in signs of motion, motor control, strength, and endurance of the limb associated with the identified meniscal or articular cartilage pathology or following meniscal or chondral surgery.
- 2.C. RISK FACTORS – MENISCUS**
Clinicians should consider age and greater time from injury as predisposing factors for having a meniscal injury. Patients who participated in high-level sports or had increased knee loads after an ACL injury are more likely to have late meniscal surgery.
- 3.C. RISK FACTORS – ARTICULAR CARTILAGE**
Clinicians should consider the patient's age and presence of a meniscal tear for the risk of having a chondral lesion subsequent to having an ACL injury. The greater a patient's age and longer time from initial ACL injury are predictor factors of the severity of chondral lesions and time from initial ACL injury is significantly associated with the number of chondral lesions.
- 4.C. DIAGNOSTIC CLASSIFICATION**
Knee pain, mobility impairments, and effusion are useful clinical findings for identifying a patient with knee pain and mobility disorders into the following International Statistical Classification of Diseases and Related Health Problems (ICD) categories: fear of the meniscus and fear of the articular cartilage; and the associated International Classification of Functioning, Disability, and Health (ICF) impairment-based category knee pain (S6002 Pain in joint) and mobility impairment (S6003 Mobility of a single joint).
- 5.C. DIFFERENTIAL DIAGNOSIS**
Clinicians should consider diagnostic classifications associated with various pathologic conditions or psychosocial factors when the patient's reported activity limitations or impairments of body function and structure are not consistent with those identified in the diagnostic 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.
- 6.C. 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 pain and mobility 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.
- 7.C. EXAMINATION – ACTIVITY LIMITATION MEASURES**
Clinicians should offer easily reproducible physical performance measures, such as single- and two-leg tests, or minute walk test, or timed up-and-go test, to assess activity limitation and participation restrictions associated with their patient's knee pain or mobility impairments and to assess the changes in the patient's level of function over the episode of care.
- 8.C. INTERVENTIONS – PROGRESSIVE KNEE MOTION**
Clinicians may utilize early progressive knee motion following knee meniscal and articular cartilage surgery.
- 9.D. INTERVENTIONS – PROGRESSIVE WEIGHT BEARING**
There are conflicting opinions regarding the best use of progressive weight bearing for patients with meniscal repairs or chondral lesions.
- 10.C. INTERVENTIONS – PROGRESSIVE RETURN TO ACTIVITY – MENISCUS**
Clinicians may utilize early progressive return to activity following knee meniscal surgery.
- 11.D. INTERVENTIONS – PROGRESSIVE RETURN TO ACTIVITY – ARTICULAR CARTILAGE**
Clinicians may need to delay return to activity depending on the type of articular cartilage surgery.
- 12.D. INTERVENTIONS – SUPERVISED REHABILITATION**
There are conflicting opinions regarding the best use of clinic-based programs for patients following arthroscopic meniscectomy to increase quadriceps strength and functional performance.
- 13.D. INTERVENTIONS – THERAPEUTIC EXERCISES**
Clinicians should consider strength training and functional exercise to increase quadriceps and hamstring strength, quadriceps endurance, and functional performance following meniscectomy.
- 14.D. INTERVENTIONS – NEUROMUSCULAR ELECTRICAL STIMULATION**
Neuromuscular electrical stimulation can be used with patients following meniscal or chondral injuries to increase quadriceps muscle strength.



DIAGNOSIS/CLASSIFICATION

II THE ICD DIAGNOSIS OF **MENISCAL TEAR** AND THE associated ICF diagnosis of joint pain and mobility impairments are made with a fair level of certainty when the patient presents with the following clinical findings^{3,6,51,78,95,115}:

- Twisting injury
- Tearing sensation at time of injury
- Delayed effusion (6-24 hours postinjury)
- History of “catching” or “locking”
- Pain with forced hyperextension
- Pain with maximum flexion
- Pain or audible click with McMurray's maneuver
- Joint line tenderness
- Discomfort or a sense of locking or catching in the knee over either the medial or lateral joint line during the Thessaly Test when performed at 5° or 20° of knee flexion

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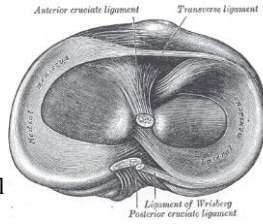
Meniscus

- Second most common knee injury
 - Incidence of 12-14%
- 10-20% of all orthopaedic surgeries in US involve meniscus
 - 850000 patients a year

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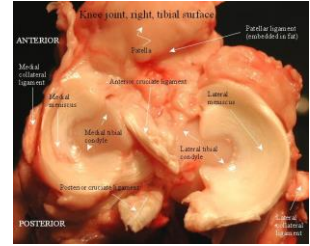
Anatomy

- Lateral
 - Circular
 - More mobile than medial
 - Connected to:
 - medial meniscus anteriorly by transverse lig
 - patella by patellomeniscal lig
 - posteriorly to popliteus mm and PCL
 - medial femoral condyle by menisofemoral lig (Ligament of Wrisberg)



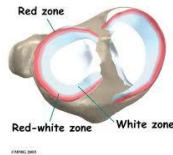
Anatomy

- Medial
 - C shaped
 - Less mobile
 - Connected to
 - transverse and menisofemoral lig like lateral
 - semimembranosus mm
 - anterior horn attached to ACL
 - posterior horn to PCL



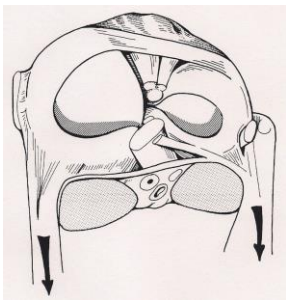
Anatomy

- Cover 2/3 of tibial plateau
- Red Zone: lateral 1/3
 - Good blood supply from capsular arteries
- White Zone: remaining 2/3
 - Poor blood supply



Function

- Load transmission
 - Manage 70% of load across knee during activities
- Shock absorption
- Stability
- Congruence
- Proprioceptive
- Transmit joint compressive forces
 - 50% EXT
 - 85% @ 90 degrees
- During flexion move posteriorly, extension move anteriorly
- During rotation, follow motion of femur
 - Most likely due to menisofemoral lig



- Semimembranosus and Popliteus pull on medial and lateral meniscus during flexion of the knee



THE ACCURACY OF MAGNETIC RESONANCE IMAGING IN DETECTING MENISCAL PATHOLOGY

S Chambers, M Jones, Y Hichla, and D Kader
J Bone Joint Surg Br 2012 94-B: (SUPP XXIX) 61.

We looked at whether the MRI report showed a tear, and this was graded Y/N. The arthroscopic report was graded for tear: Y/N. 66 patients had a positive scan. 64 of these were found to have a tear at surgery. 37 scans were reported as "no tear", of which 4 were found to have a tear at surgery. Nine scans were not easy to classify as they were descriptive.

In our series of 112 knees, MRI was 90.5% sensitive, 89.5% specific and 90.1% accurate.

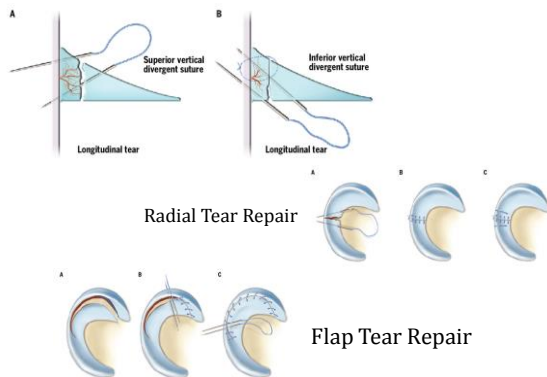
When a definite diagnosis of "tear", or "no tear" was made at scan, there were two false positives and four false negatives. False positives may be unnecessarily exposed to the risks of surgery. Patients with negative scans had a mean delay to surgery of 33 weeks compared to 18 weeks for patients with positive scans. False negatives may wait longer for their surgery. Two of the false negative scans clearly showed meniscus tears which were missed by the reporting radiographer. In our series the scan itself was more accurate than the reporting. It is important to have an experienced musculoskeletal radiologist to minimise the number of missed tears. It is also important for surgeon to check the scan as well as the report.

Meniscal Repair

FRANK R. NOYES, MD* • TIMOTHY R. HECKMANN, PL.ATC† • SUE D. BARBER-WESTIN, BS‡

Meniscus Repair and Transplantation: A Comprehensive Update

TABLE 1	INDICATIONS AND CONTRAINDICATIONS FOR MENISCUS REPAIR
Indications	
• Meniscus tear with fibroligamentary joint line pain	
• Patients younger than 50 years of age or patients in their thirties who are athletically active	
• Concurrent knee ligament reconstruction or osteotomy	
• Meniscus tear reducible, good tissue integrity, normal position in the joint once repaired	
• Peripheral single longitudinal tears: red-red, 1 plane; repairable in all cases, high success rates	
• Middle-third region: red-white (vascular supply present) or white-white (no blood supply); often repairable with reasonable success rates	
• Outer-third and middle-third regions, longitudinal, radial, horizontal tears: red-white, 1 plane; often repairable	
Contraindications	
• Meniscus tears located in inner-third region	
• Chronic degenerative tears in which the tissue is of poor quality and not amenable to suture repair	
• Longitudinal tears less than 30 mm in length	
• Incomplete radial tears that do not extend into the outer-third region	
• Patients older than 60 years of age	
• Patients unwilling to follow postoperative rehabilitation program	



Meniscal Transplantation

TABLE 2	INDICATIONS AND CONTRAINDICATIONS FOR MENISCUS TRANSPLANTATION
Indications	
<ul style="list-style-type: none"> • Prior meniscectomy • Patients 50 years of age or younger • Pain in the meniscus-bearing tibiofemoral compartment • No radiographic evidence of advanced joint deterioration, >2 mm of tibiofemoral joint space on 45° weight-bearing posteroanterior radiographs • No or only minimal bone exposed on tibiofemoral surfaces • Normal axial alignment 	
Contraindications	
<ul style="list-style-type: none"> • Advanced knee joint arthritis with flattening of the femoral condyles, concavity of the tibial plateau, and osteophytes that prevent anatomic seating of the meniscus transplant • Uncorrected varus or valgus axial malalignment • Uncorrected knee joint instability, anterior cruciate ligament deficiency • Knee arthralgia • Significant muscular atrophy • Prior joint infection with subsequent arthritis • Symptomatic, noteworthy patellofemoral articular cartilage deterioration • Obesity (body mass index >30 kg/m²) • Prophylactic procedure (asymptomatic patients with no articular cartilage damage) 	

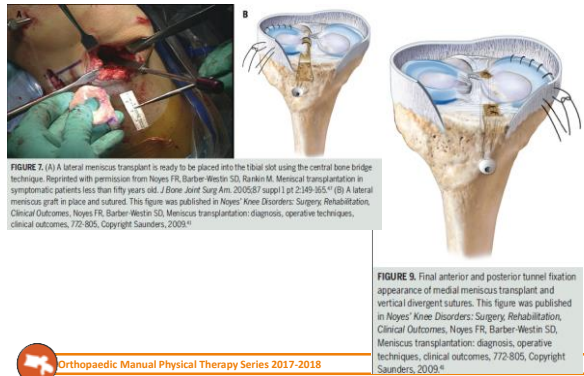


FIGURE 7. (A) A lateral meniscus transplant is ready to be placed into the tibial slot using the central bone bridge technique. Reprinted with permission from Noyes FR, Barber-Westin SD, Rankin M. Meniscus transplantation in symptomatic patients less than fifty years old. *J Bone Joint Surg Am.* 2005;87 suppl 1 pt 2:149-165. (B) A lateral meniscus graft in place and sutured. This figure was published in Noyes' *Knee Disorders: Surgery Rehabilitation, Clinical Outcomes*, Noyes FR, Barber-Westin SD, Meniscus transplantation: diagnosis, operative techniques, clinical outcomes, 772-805, Copyright Saunders, 2009.⁶

FIGURE 9. Final anterior and posterior tunnel fixation appearance of medial meniscus transplant and vertical divergent sutures. This figure was published in Noyes' *Knee Disorders: Surgery Rehabilitation, Clinical Outcomes*, Noyes FR, Barber-Westin SD, Meniscus transplantation: diagnosis, operative techniques, clinical outcomes, 772-805, Copyright Saunders, 2009.⁶

TABLE 3	REHABILITATION PROTOCOL SUMMARY FOR MENISCUS REPAIR AND TRANSPLANTS*								
	Postoperative Weeks				Postoperative Months				
	1-2	3-4	5-6	7-8	9-12	4	5	6	7-12
Stair									
Long leg protractor	G, A, T	G, A, T	G, T						
Range of motion (meniscus repair)									
0° to 90°	X								
0° to 120°			X						
0° to 135°				X					
Weight bearing									
Toe touch to full body weight	P	P							
Three quarters to full	G, T, A								
Toe touch to quadrupedal body weight		G, T, A	G, A						
Half to three quarters body weight				G, A					
Full					T				
Fatigue mobilization	X	X	X	X					
Strengthening									
Hamstring, gastrocnemius, tibialis anterior, quadriceps	X	X	X	X	X	X	X	X	X
Stair training									
Quadriceps isometric, straight leg raises, sit-ups	X	X	X	X	X	X	X	X	X
Knee extension									
Closed-chain gait retraining, low volume, walk-ups, mini-squats	P								
Knee flexion/hamstring curls (90°)			P	C	X	X	X	X	X
Knee extension quadriceps (90°-30°)			X	X	X	X	X	X	X
Hip abduction/adduction, walking			X	X	X	X	X	X	X
Leg press (90°-80°)			P	P	X	X	X	X	X
Balance/proprioceptive training									
Weight shifting, mini-squats, BAPS, BESS, plyometrics	P	X	X	X	X	X	X	X	X
Conditioning									
Upper-body ergometer		X	X	X					
Stair (stationary)					X	X	X	X	X
Aquatic program					X	X	X	X	X
Covering (biking)					P	X	X	X	X
Walking					X	X	X	X	X
Stair climbing on level					P	P	P	P	P
Stair machine					P	P	P	P	P
Staircase					P	P	P	P	P
Swimming									
Cycling									
Interval training, figure-eight*									
Half sprint†									

*Conditioning: A, self-paced moderate exercise; BAPS, Biomechanical Ankle Proprioceptive System; BESS, Biomechanical Balance System; C, complete (stable) and moderate exercise alternating from middle third region; P, peripheral nervous system; T, transplantation; X, all meniscus repair and transplants.
 †Modified from Endreanov et al.¹¹ weekly progression.
 Returns to running, walking, and full sports based on multiple criteria. Patients with noticeable articular cartilage damage are advised to return to light recreational activities only.

Rehab

- Dependent on type and location of repair/transplant
 - Physician directed
- Generally
 - Long leg brace x6 weeks
 - Restricted weight bearing at least 3 weeks
 - Flexion ROM restricted to 90 week 1, 120 week 4, 135 week 6
 - Biking week 7, straight running month 4, cutting month 5, return to sport month 5



ARTICULAR CARTILAGE

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Articular Cartilage

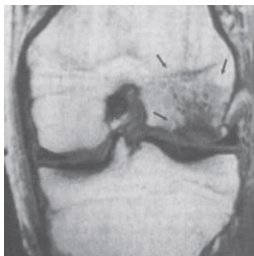
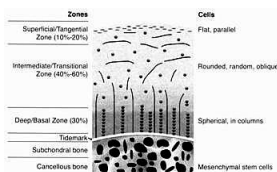
- Incidence
 - 60-70%
 - Isolated 30%
 - Non isolated 70%
- Most commonly at medial femoral condyle and patella articular surface
- Medial meniscus tears and ACL rupture most common concomitant injuries
 - 37% and 36%



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Anatomy



The ICD diagnosis of an **articular cartilage defect** and the associated ICF diagnosis of joint pain and mobility impairments is made with a low level of certainty when the patient presents with the following clinical findings¹⁶:

- Acute trauma with hemarthrosis (0-2 hours) (associated with osteochondral fracture)
- Insidious onset aggravated by repetitive impact
- Intermittent pain and swelling
- History of “catching” or “locking”
- Joint line tenderness



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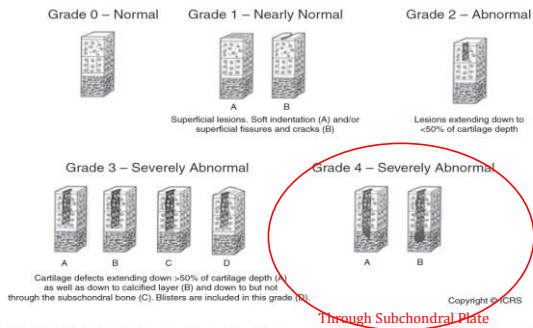


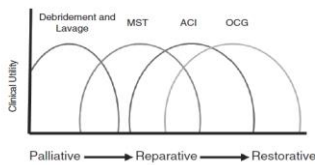
FIGURE 2. ICRS Grading. The International Cartilage Repair Society grading system for normal and abnormal articular cartilage. Pii with kind permission from the International Cartilage Repair Society.

Treatment Options

- Conservative/Palliative
 - Debridement/Lavage
- Reparative
 - Subchondral Drilling
 - Microfracture
- Restorative
 - OATS
 - ACI/MACI

Treatment Options

- Debridement/Lavage
- Marrow Stimulating
- Autologous Chondrocyte Implantation
- Osteochondral Grafting



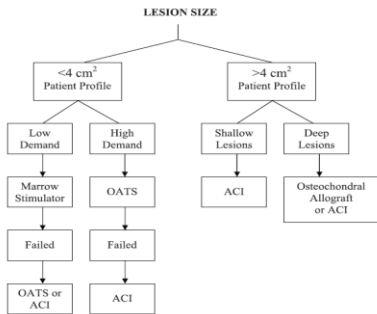
Treatment Selection in Articular Cartilage Lesions of the Knee

A Systematic Review

Joris E. J. Bekkers, MD, Melanie Inklaar, MD, and Daniël B. F. Saris, MD, PhD

Results: Lesion size, activity level, and age were the influencing parameters for the outcome of articular cartilage repair surgery. Lesions greater than 2.5 cm² should be treated with sophisticated techniques, such as autologous chondrocyte implantation or osteochondral autologous transplantation, while microfracture is a good first-line treatment option for smaller (<2.5 cm²) lesions. Patients who are active show better results after autologous chondrocyte implantation or osteochondral autologous transplantation when compared with microfracture. Younger patients (<30 years) seem to benefit more from any form of cartilage repair surgery compared with those over 30 years of age.

Conclusion: Lesion size, activity level, and patient age are factors that should be considered in selecting treatment of articular cartilage lesions of the knee. In addition, these factors are a step toward evidence-based, instead of surgeon-preferred, treatment of articular cartilage lesions of the knee.



Bulletin of the NYU Hospital for Joint Diseases 2007;65(1):51-60

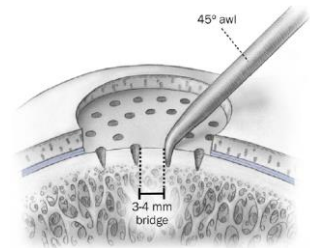


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Micro fracture

- Marrow stimulation technique
- Most common
- Simple, safe, cheap
- Injury/inflammatory response
- Fibrous Clot formed
- < 2-4 cm lesion



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Successful Outcome

1. Remove calcified cartilage layer – Do not abrade subchondral bone
2. Penetrate Subchondral bone (awl) with 1-2 mm between to allow soft tissue in growth to adhere
3. Maintain post op ROM (CPM)
4. Post op – partial weight bearing (50% x 6 weeks)
5. Realignment/stabilizing procedure concurrently – DJD, Patellar tracking, ligt repair/reconstruction



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OATS/Mosaicplasty

TABLE 1. Indications for mosaicplasty.

- Focal chondral and osteochondral defects of weight-bearing articular surfaces of the knee
- Defects of other diarthrodial surfaces of the talus, humeral capitulum, and femoral head
- Patient less than 50 years of age
- The ideal diameter of the defect is between 1 and 4 cm²
- Concurrent treatment of instability, malalignment, and meniscal and ligament tears is essential
- Patient compliance is critical (ie, weight-bearing limitation)



J Orthop Sports Phys Ther • Volume 36 • Number 10 • October 2006



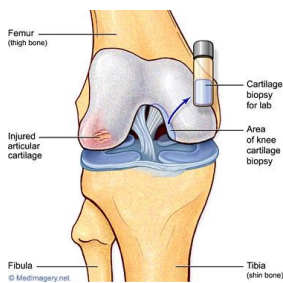
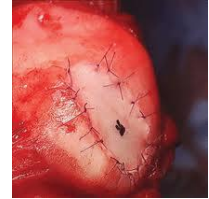
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Autologous Chondrocyte Implantation (ACI)

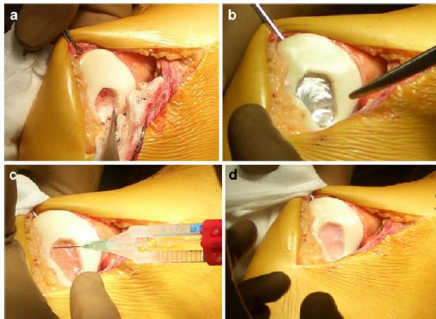
- 2 surgical stages:
 - Chondral biopsy
 - Implantation of cells into lesion
- Full thickness lesions – Femoral condyle, trochlear groove
- Unipolar lesions
- <50 yrs old
- Larger lesions 2-8 cm
- Normal alignment/stability
- Hyaline cartilage = Better Outcomes?



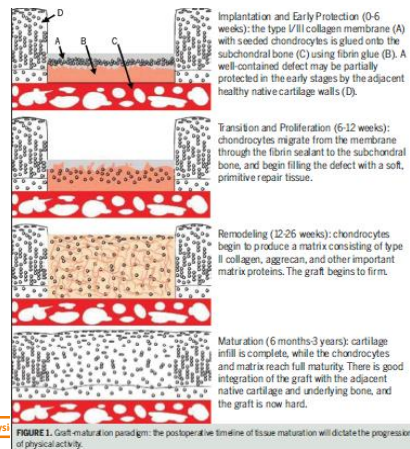
Matrix Induced ACI

- ACI surgery but without periosteum harvest
- 2 stage surgery
 - Harvest of cells
 - Implantation of membrane
- Use fibrin glue to adhere membrane

Fig. 3 Surgical stage of matrix-induced autologous chondrocyte implantation (MACI) in patellar chondral lesion. a Debridement and shaping of chondral lesion. b Sizing of lesion for preparing of the membrane. c Filling the center with fibrin glue. d Pressing the membrane and looking for air bubbles and glue leak before moving the knee



• Graft Healing Course Following MACI



Summary

- Improved outcomes for <30yo
- Improved outcomes for more active individuals
- For lesions >4cm, better outcomes with ACI or MACI
- All surgical interventions showed improved outcome measures short and long term
- Return to sport fastest with OATS (7mo), longest with ACI (18-25mo)
- Lack of conclusive research on best approach

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-1 Outcomes Following Microfracture for Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age (yr)	Average Duration of Follow-up (yr)	Average Size of Lesion (cm ²)	Outcome*
Steadman et al. ¹⁶ (2003)	71	30.4	11.3	2.774	Lysholm score ^{7,21} : 59→89; Tegner score ^{7,21} : 3→6
Steadman et al. ¹⁵ (2003)	25	28.2	4.5	Not recorded	Lysholm score ^{7,21} : 68→90; 76% returned to NFL in 1 yr
Knutsen et al. ²³ (2004)	40	32.2	2	4.80	Lysholm score ^{7,21} : 53→76; SF-36 physical score: 36→46
Mithoefer et al. ²² (2005)	48	41.7	3.6	4.82	Good to excellent: 67%
Gudas et al. ¹⁴ (2005)	29	24.3	3.1	2.80	Good to excellent: 52%
Gobbi et al. ²⁴ (2005)	53	38	6	4.00	Lysholm score ^{7,21} : 56→87; Tegner score ^{7,21} : 3.2→5; IKDC score ²⁰ : 70% nearly normal

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-2 Outcomes Following Osteochondral Autograft Transplantation in Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age (yr)	Average Duration of Follow-up (yr)	Average Size of Lesion (cm ²)	Outcome*
Hangody and Fules ⁹³ (2003)	831	Unknown	10	Unknown	Good to excellent: 92% of femoral lesions, 87% of tibial lesions, 79% of patellofemoral lesions
Marcacci et al. ¹²⁸ (2007)	30	29.3	7	<2.5	Good to excellent: 77%; IKDC score ^{27,28} : 35→72
Oursini et al. ⁹⁸ (2006)	19	33.1	2.7	1-2.5	Good to excellent: 85%; Lysholm score ^{27,28} : 46→88
Chow et al. ¹²⁹ (2004)	30	44.6	3.7	1-2.5	Good to excellent: 83%; Lysholm score ^{27,28} : 44→88
Minares and Tytherleigh-Strong ⁹⁷ (2007)	20	14.3	3.4	Unknown (osteocondritis dissecans)	Clinically normal by 18 mo; healing of osteochondritis dissecans lesions by 6 mo
Yoo et al. ⁹⁹ (2008)	22	30	2.1	1.7	IKDC score ⁹⁶ : 47→94 for isolated patellar lesions; 71% with complete incorporation on magnetic resonance imaging

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Management of Articular Cartilage Defects of the Knee

Asheesh Bedi, Brian T. Feeley and Riley J. Williams, III
J Bone Joint Surg Am. 2010;92:994-1009. doi:10.2106/JBJS.I.00895

TABLE E-4 Outcomes Following Autologous Chondrocyte Implantation in Isolated Articular Cartilage Lesions

Study	No. of Patients	Average Age (yr)	Average Duration of Follow-up (yr)	Average Size of Lesion (cm ²)	Outcome*
Brittberg et al. ⁹³ (1994)	23	27	3.7	1.6-6.5	Good to excellent: 14/16
Peterson et al. ¹⁰¹ (2000)	25	32.2	4.2	4.2	Good to excellent for femoral condyles: 92%
Peterson et al. ¹²⁸ (2002)	18	40.8	7.4	1.3-12	Tegner score ¹²⁸ : 6→9.8; good to excellent: 17/18
Bentley et al. ⁹⁹ (2003)	50	31	1.5	4.7	Good to excellent: 88%
Zaslav et al. ⁹⁶ (2009)	126	34.5	3.9	4.6	Treatment success: 76%; modified Cincinnati score ^{27,28} : 3.3→6.3

*The values before and after the arrows indicate the preoperative and follow-up scores (in points), respectively.

Systematic Review

Treatment of Chondral Defects in the Athlete's Knee

Joshua D. Harris, M.D., Robert H. Brophy, M.D., Robert A. Siston, Ph.D., and David C. Flanigan, M.D.

Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 26, No 6 (June), 2010; pp 841-852

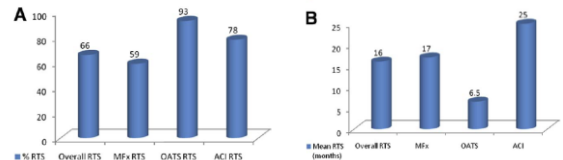
Improved outcomes after cartilage repair or restoration in athletes were observed in smaller defects in younger patients with a shorter preoperative duration of symptoms, without any prior surgical intervention, and higher preinjury and postoperative levels of sports. Results of microfracture appeared inferior in rate of return and performance on return relative to ACI or OATS, and clinical outcomes in this patient population may deteriorate with time after microfracture. Although the literature suggests that ACI and OATS may provide better results for athletes compared with microfracture, only further randomized prospective clinical trials will elucidate the optimal surgical treatment for focal chondral injury in the athlete's knee.

Systematic Review

Treatment of Chondral Defects in the Athlete's Knee

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KAI MITHOEFER, MD¹ • KAREN HAMBLY, PT, PhD, MCSP² • DAVID LOGERSTEDT, PT, PhD, MPT, SCS³
 MARGHERITA RICCI, MD⁴ • HOLLY SILVERS, MPT⁵ • STEFANO DELLA VILLA, MD⁶

Current Concepts for Rehabilitation and Return to Sport After Knee Articular Cartilage Repair in the Athlete

| MARCH 2012 | VOLUME 42 | NUMBER 3 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY

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TABLE 1		FACTORS TO CONSIDER DURING INDIVIDUALIZED CARTILAGE REPAIR REHABILITATION	
Considerations/Specific Factors		Implications	
Individual			
Athlete's age		Slower cartilage repair with increased age	
Body mass index		More gradual rehabilitation progression with body mass index greater than 30 kg/m ²	
Type of sport		Higher demand on repair tissue in impact sports	
Competitive level		Competitive athletes have better outcomes	
Psychological		Less fear of reinjury and higher self-efficacy are associated with better outcomes	
Lesion/defect			
Defect size		Smaller defects frequently improve faster with rehabilitation	
Repair technique		More rapid rehabilitation progression with restorative techniques	
Defect location		Immediate weight bearing for patellofemoral defect (knee brace locked in full extension)	
Duration of symptoms		Longer recovery if symptoms persist longer than 12 months (deconditioning)	
Cartilage quality		Slower rehabilitation progression with generalized joint chondropenia	
Concomitant injuries			
Concomitant procedures		Modified protocols for anterior cruciate ligament reconstruction, meniscal repair, osteotomy, etc	
Meniscus status		Slower rehabilitation progression after meniscectomy (especially lateral meniscus)	

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Phases of Healing and Rehab

- **Biologic Phase**
 - Phase I
 - Graft integration and stimulation
 - Phase II
 - Matrix production and organization
 - Phase III
 - Repair cartilage maturation and adaptation
- **Rehab Phase**
 - Phase I
 - Protection and joint activation
 - Phase II
 - Progressive loading and functional joint restoration
 - Phase III
 - Activity restoration

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Rehabilitation

- **Phase I**
 - **Protection and Joint Activation**
 - Weeks 1-6
 - Effusion control
 - Partial weightbearing
 - NMES/Quad activation therex
 - Gradual improving ROM

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Rehabilitation

- Phase II
 - Progressive loading and functional joint restoration
 - Week 6-6month
 - Full ROM/weightbearing
 - Progress proprioceptive training
 - Progress concentric to eccentric and static to dynamic strengthening and neuromuscular control
 - Introduce progressive plyometrics /loading activities



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Rehabilitation

- Phase III
 - Activity restoration
 - Sport specific/on field rehab
 - 6-18 months (depending procedure, graft size, healing via imaging)



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TABLE 4	WEIGHT-BEARING GUIDELINES AND CRITERIA FOR PROGRESSION AFTER ARTICULAR CARTILAGE REPAIR
Phase 1: Weight-Bearing Guidelines	
<ul style="list-style-type: none"> • Femoral defects <ul style="list-style-type: none"> - Restorative techniques (OATS/allgraft): touch-down loading for 2 wk, then progress to full weight bearing by 4 to 6 wk - Reparative techniques (microfracture/AC): touch-down loading for 2 wk, then progress by 25% body weight per wk • Patella/trochlear defects <ul style="list-style-type: none"> - Immediate weight bearing with brace locked in 0° to 30° of knee flexion 	
Progression Criteria to Go from Phase 1 to Phase 2	
<ul style="list-style-type: none"> • Full passive ROM equal to the nonoperated knee • Minimal or absent pain (VAS less than 3/10) • Minimal or no effusion (grade 0 or 1+) • Recovery of muscular activation • Recovery of normal gait cycle (equal stride length and stance time between limbs, no limp) 	
Progression Criteria to Go from Phase 2 to Phase 3	
<ul style="list-style-type: none"> • Full and painless ROM • No or minimal pain (VAS less than 3/10) • No or minimal effusion (grade 0 or 1+) • Maximum peak torque difference of less than 20% between limbs on isokinetic test • Hip performance difference of less than 10% between limbs • Self-report outcomes greater than 50% • Ability to run on a treadmill at 8 km/h for more than 10 min • MRI evaluation of the repaired cartilage to evaluate repair tissue 	
<p><i>Abbreviations: ACI, autologous chondrocyte implantation; MRI, magnetic resonance imaging; OATS, osteochondral autograft transplantation system; ROM, range of motion; VAS, visual analog scale</i></p>	



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Clinical Rehabilitation Guidelines for Matrix-Induced Autologous Chondrocyte Implantation on the Tibiofemoral Joint

PETER K. EDWARDS, PT, MSc^{1,2} • TIMOTHY ACKLAND, PhD, FASMP³ • JAY R. EBERT, PT, PhD²

FEBRUARY 2014 | VOLUME 44 | NUMBER 2 | JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY

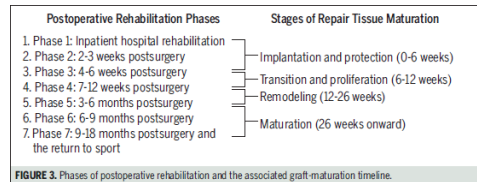


FIGURE 3. Phases of postoperative rehabilitation and the associated graft-maturation timeline.

- Excellent resource for rehabilitation protocol and progression



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