

Rehabilitation after ACL Reconstruction: Practice Guidelines

Primary Surgery: ACL Reconstruction

Secondary Surgery (if applicable): Meniscal repair, meniscectomy, microfracture, chondroplasty, MCL injury, posterior lateral corner injury (appendix 1)

Expected # of visits: 20-46

Outcome Measures: KOS-ADLS, IKDC, ACL-RSI (short form) and Marx Activity Scale

Operational Definitions:

Phase Goals: Primary impairments targeted during a particular phase

Milestones: Minimum objective criteria required to progress to the next phase of rehab

Knee Joint Effusion Assessment: Sweep Test to assess intraarticular joint irritation (appendix 2)

Soreness Rules: To assess response to loading (appendix 3)

Full Knee Extension Range of Motion (ROM): Aim for symmetrical to uninvolved limb

Pre-Operative Rehabilitation

Phase Goals: Begin as soon as possible following initial injury to re-establish the following goals prior to surgery

- Full active (AROM) and passive (PROM) knee extension
- Knee flexion ROM within 10° of uninvolved limb
- Trace to zero knee effusion
- No knee extension lag with straight leg raise (SLR)
- Quadriceps Strength Index (QI) ≥ 80% of uninvolved limb
 - o Retain values for post-operative comparison to minimize overestimation of strength

Patient Education:

- Importance of prehab for optimal post-operative outcomes
- What to do immediately after surgery (0-48 hours)
- Anticipated return to sport timeline: 9-12 months, allografts 12+ months
- Expected outcomes
 - o Return to prior level of competition is often difficult, but possible
 - o Osteoarthritis risk



Immediate Post-Operative Phase (week 1)		
Phase Goals: - At least 0° knee extension ROM - Improve quad activation - Decrease knee joint effusion - Decrease pain - Gait retraining on crutches	Milestones: - ROM = 0-90° - Active quad contraction with superior patellar glide - Walking on crutches with superior patellar glide	
Treatment Strategies:		
Total Visits: 1-2 visits PT Frequency: 1-2x per week HEP Frequency: 4-6x per day	ROM:	- Flexion 0-90°: wall slides, heels slides with strap, stationary bike - Extension: heel prop, extension overpressure
Muscle Performance:		- Quad sets, long arc quad 90-0° (LAQ), standing and prone terminal knee extensions (TKEs), straight leg raise (SLR), ankle pumps - Optional: low intensity Blood Flow Restriction (BFR) strength training for patients limited by pain or poor load tolerance
Manual Therapy:		- Patellar mobilization, flexion/extension PROM
Electric Stimulation:		- NMES dosed @ ≥ 50% of isometric MVIC (appendix 5)
Gait Training:		- WBAT on crutches with active quadriceps contraction
Modalities:		- Ice, elevation and compression (e.g. sleeve, compression wrap or donut wrap)
<p>Avoid unnecessary weight bearing throughout day to minimize effusion and pain. Elevate knee above heart level and ice as often as possible.</p> <p>Criteria to discontinue use of brace/knee immobilizer (if used): SLR without lag, no increased pain or effusion with weight bearing and visible quad activation while ambulating in clinic. Crutches should be used as needed to normalize gait pattern and facilitate reduction in knee effusion.</p> <p>Quadriceps MVIC Strength Testing: Isometric testing performed once able to assume test position (45-90° knee flexion) without pain. Utilize to appropriately dose NMES for quad strengthening each visit.</p> <p>Home Exercise Program Recommendations: Quad sets 5-10 sets of 100 x 5-10" per day, SLR (assisted as needed) 3 x 10, LAQ (90-0°) 30 x 5", heel slides/seated assisted knee flexion/wall slides 30 x 5", heel prop with ice 5 x 10 minutes per day, self-mobilization of patella 20 x 5" each direction</p>		



Early Post-Operative Phase (week 2-3)		Phase Goals:
<ul style="list-style-type: none"> - Continue progressive impairment resolution - Normalize gait - SLR without a lag 		Milestones: <ul style="list-style-type: none"> - ROM = 0-115° (aim for hyperextension symmetrical to contralateral) - Walking without crutches or immobilizer - KOS-ADLS ≥ 65% - Effusion < 2+
Treatment Strategies:		
Total Visits: 5-6 visits PT Frequency: 2x per week HEP Frequency: 4-6x per day	ROM:	<ul style="list-style-type: none"> - Continuation of previous phase exercises - Add bag/prone hangs with light weight if lacking full knee extension for low load long duration stretch
	Muscle Performance:	Quadriceps strengthening (90-0°) <ul style="list-style-type: none"> - <i>Open kinetic chain (OKC):</i> multi-angle isometrics, LAQ with cuff weights/resistance band/knee extension machine, variable range isokinetics
	Neuro Re-education:	Global Lower Extremity Strengthening <ul style="list-style-type: none"> - <i>Closed kinetic chain (CKC):</i> wall sits, air squats - <i>Accessory strengthening:</i> core, hip and calf strengthening, hamstring curls (appendix 1: Precautions and concomitant procedure modifications) - <i>Optional:</i> BFR strength training
	Manual Therapy:	<ul style="list-style-type: none"> - Incision mobilizations PRN (once healed), patellar mobilizations, flexion/extension stretching
	Electric Stimulation:	<ul style="list-style-type: none"> - NMES dosed @ ≥ 50% of isometric MVIC (appendix 5)
	Gait Training:	<ul style="list-style-type: none"> - Cue “land on bent knee, push knee back while squeezing quad,” retro walking to promote TKE, progress to functional brace as swelling permits (if used)
	Modalities:	<ul style="list-style-type: none"> - Continue for effusion management
	<p>Criteria to discontinue crutches: Normal gait pattern with good active quad control, no lag with SLR and effusion ≤ 2+</p> <p>Effusion monitoring: Assess response to exercises frequently, stay same intensity or decrease if effusion increases; do not progress exercise with a 2+ effusion. Refer to Soreness Rules (Appendix 2)</p> <p>Pain monitoring: Modifications to exercise ROM and load to minimize quad and patellar tendon graft site irritation (keep pain < 5/10)</p> <p>Home Exercise Program Recommendations: Quad sets 5-10 sets of 100 x 5-10” per day, SLR (assisted as needed) 3 x 10, LAQ (90-0°) with resistance 30 x 5”, heel slides/seated assisted knee flexion/wall slides 30 x 5”, heel prop with ice 5 x 10 minutes per day, self-mobilizations of patella 20 x 5” each direction, frequent short bouts of ambulation (3-5 minutes/hour)</p>	



Intermediate Post-Operative Phase (week 4-6)

<p>Phase Goals:</p> <ul style="list-style-type: none"> - Complete impairment resolution - Progressive quadriceps strengthening - Restoration of full ROM - Resumption of ADLs 	<p>Milestones:</p> <ul style="list-style-type: none"> - Flexion ROM within 10° of uninvolved limb - Quad strength MVIC ≥ 60% of uninvolved (See Comment Below) - Effusion ≤ 1+ - Normal gait pattern - Reciprocal stair climbing
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Treatment Strategies:

<p>Total Visits: 11-12 visits</p> <p>PT Frequency: 2x per week</p> <p>HEP Frequency: 1-2x per day</p>	ROM/Manual Therapy:	<ul style="list-style-type: none"> - PRN for knee ROM and mobility deficits - Formally assess hip and ankle for impairments
	Muscle Performance:	<p>Quadriceps strengthening (90-0°)</p> <ul style="list-style-type: none"> - <i>OKC</i>: Progressive isokinetics (e.g. speed and ROM), knee extension machine <p>Global Lower Extremity Strengthening</p> <ul style="list-style-type: none"> - <i>CKC</i>: leg press, single leg squats, step ups/downs, forward and side lunges, bridges - <i>Accessory Strengthening</i>: core, hip and calf strengthening, hamstring curl machine (appendix 1) - <i>Optional</i>: BFR Strength Training (discontinue when able to tolerate >70% 1-RM load)
	Neuro Re-education:	<ul style="list-style-type: none"> - Balance and proprioceptive activities on variable surfaces (e.g. BOSU, foam), perturbation progressions
	Aerobic Training:	<ul style="list-style-type: none"> - Bike, elliptical, stair master (10 minutes minimum)
	Electric Stimulation:	<ul style="list-style-type: none"> - NMES dosed @ ≥ 50% of isometric MVIC (see appendix 5)
	Gait Training:	<ul style="list-style-type: none"> - PRN for remaining abnormalities
	Modalities:	<ul style="list-style-type: none"> - PRN for pain and effusion

Effusion monitoring and Pain Monitoring: Continue as outlined above

Preferred methods for assessing quad strength: Isokinetic dynamometer (e.g. Biodex) in isometric or isokinetic (60/90/120 degrees/sec) mode, handheld dynamometry with fixation or 1 repetition maximum on a knee extension machine 90-45° or 90°-0° (week 7+)

Quadriceps Strength Index (QI): Monitor for bilateral strength loss after injury. QI should be calculated using pre-injury data for the uninvolved (if available) or the highest value collected during rehab to avoid overestimating quadriceps strength in the involved limb.

Home Exercise Program Recommendations:
SLR with resistance 3 x 10, LAQ with resistance 30 x 5", prone quad stretch 3 x 30", SLS 10 x 15", squats (0-90°) 3 x 10, heel raises 3 x 10, self-patellar mobs PRN 20 x 5", aerobic conditioning 10-15 minutes, step ups 3 x 10, single leg squat eccentrics 3 x 10, planks 5 x 30", hip strengthening 3 x 10



Late Post-Operative Phase (week 7-9)		
Phase Goals:		Milestones:
<ul style="list-style-type: none"> - Improve tolerance to loading - Improve aerobic conditioning - Increase variability - Improve ADL function and efficiency 		<ul style="list-style-type: none"> - Full and symmetrical ROM - Quad strength \geq 70% of uninvolved - Effusion \leq 1+ - Normal gait pattern - KOS-ADLS \geq 70%
Treatment Strategies:		
Total Visits: 17-18 visits	Muscle Performance:	Concentric and eccentric overload @ 60-75% 1-RM <i>Quadriceps (90-0°), posterior chain and accessory strengthening:</i> - Knee extension machine, leg press, SL variations, hamstring curls, weighted step ups and lunges
PT Frequency: 2x per week	Neuro Re-education:	- Perturbation training and higher-level balance progressions (e.g. multi-task, ball toss, incorporate sport specific equipment as appropriate)
HEP Frequency: 2-3x per week	Aerobic Training:	- Increase duration and intensity
	Electric Stimulation:	- May discontinue if quad strength \geq 80%
	Gait Training:	- PRN for remaining abnormalities
	Modalities:	- PRN for pain and effusion
Exercise Constraints:		
<p><i>External load constraints for strengthening examples:</i></p> <ul style="list-style-type: none"> - 1-RM percentage: 65-85% of 1-RM, 5-8 reps, 3-5 sets - 5-RM percentage: 80-100% of 5-RM, 5-8 reps, 3-5 sets - Rate of loading/tempo: 3-5 second concentric, 0-2 second pause at transition, 3-5 second eccentric (Silbernagel 2017) - Work/rest ratio: 3-4 minutes between sets (variable based on exercise goal) <p><i>Internal load constraints for strengthening examples:</i></p> <ul style="list-style-type: none"> - Rate of perceived exertion: working sets at 6-8/10 RPE scale - Repetitions in reserve (RIR): prescribe load in which patient can complete 5-8 reps through prescribed ROM with a theoretical ability to complete 2-3 additional reps before maximal fatigue. If upon completion of set the patient reports RIR \geq 3-4 repetitions, increase load - Daily Adjustable Progressive Resistive Exercise (DAPRE) method: utilizes working weight and maximal number of reps completed during set to determine load adjustments (see Knight 1979) 		
Home Exercise Program Recommendations:		
Resisted squats (0-90°) 5 x 8, LAQ with heavy resistance 3 x 15, unilateral heel raises 3 x 10, aerobic conditioning 15-30 minutes, resisted step ups 3 x 10, SL squats 3 x 10, planks 5 x 60", resisted SL RDLs 3 x 12, hip strengthening 3 x 10		



Transitional Phase I (week 10-12)		
Phase Goals: - Initiate transition to gym-based program and/or supervised training with ATC or strength coach if appropriate	Milestones: - Full and pain free ROM - Quad strength \geq 75% of uninvolved - Effusion \leq 1+ - KOS-ADLS \geq 80%	
Treatment Strategies:		
Total Visits: 20-24 visits	Muscle Performance:	Concentric and eccentric overload @ 60-85% 1-RM <i>Progressive quadriceps and lower extremity strength training:</i> - Knee extension machine, deadlifts, barbell squatting, light leg press/shuttle plyometrics (week 12+)
	PT Frequency: 1-2x per week	Neuro Re-education: - Higher-level balance progressions (e.g. reactive vs anticipatory, incorporate sport specific equipment as appropriate)
HEP Frequency: 2-3x per week	Aerobic Training:	- Initiate Alter-G or pool running
	Electric Stimulation:	- May discontinue if quad strength \geq 80%
	Modalities:	- PRN for pain and effusion

Transitional Phase II (week 13-16)		
Phase Goals: - Initiate running - Transition to gym-based program and/or supervised training with ATC or strength coach if appropriate	Milestones: - Quad strength \geq 80% of uninvolved - Effusion \leq trace - No pain or swelling with running	
Treatment Strategies:		
Total Visits: 24-32 visits	Muscle Performance:	Concentric and eccentric overload @ 60-85% 1-RM <i>Progressive quadriceps and lower extremity strength training:</i> - Light power training (e.g. cleans, snatches), circuit training
	PT Frequency: 1-2x per week	Neuro Re-education: - Controlled landing mechanics (begin with 2" box drops) and higher-level balance progressions as appropriate
HEP Frequency: 2-3x per week	Aerobic Training:	- Continue Alter-G or pool running, progress duration and intensity as appropriate
	Return to Level Ground Running Criteria: - Quadriceps strength \geq 80% - Effusion \leq trace - Understanding of soreness rules Appendix 1 for considerations specific to allografts Appendix 6 for full running progression	



Transitional Phase III (months 4-6)

<p>Phase Goals:</p> <ul style="list-style-type: none"> - Initiate sprint progression - Initiate agilities - Initiate jumping - Initiate Secondary Prevention Program 	<p>Milestones:</p> <ul style="list-style-type: none"> - Quad strength \geq 85% of uninvolved - Hop testing \geq 85% - KOS-ADLS \geq 85% - ACL RSI > 60% (at 6 months)
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Treatment Strategies:

<p>Total Visits: 27-38 visits</p>	<p>Muscle Performance: Concentric and eccentric overload @ 60-85% 1-RM <i>High intensity strength training:</i></p> <ul style="list-style-type: none"> - Heavy barbell squats, deadlifts, kettlebell swings, Nordic hamstring curls, lateral sled pulls
<p>PT Frequency: 1-2x per month</p>	<p>Stage 1 Sprint Progression Criteria:</p> <ul style="list-style-type: none"> - Quadriceps strength \geq 80% - Effusion \leq trace - Understanding of soreness rules - Completion of running progression <p>Appendix 8 for Stage 1 Sprint Progression</p>
<p>HEP Frequency: 3-4x per week</p>	<p>Return to Agilities Criteria (e.g. forward and lateral cone shuttle, figure-8) <i>Progress from pre-planned to reactive, include sports specific equipment as appropriate</i></p> <ul style="list-style-type: none"> - Quadriceps strength \geq 80% - Effusion \leq trace - Hop testing \geq 80% (appendix 7) - Understanding of soreness rules - Completion of running and Stage 1 Sprint Progression <p>Appendix 1 for considerations specific to allografts</p>
<p>Supervised by ATC or Strength Coach if able</p>	<p>Return to High Intensity Plyometrics (e.g. box jump, drop jumps, broad jump): <i>Progress from two-feet landing to one-foot landing, single plane to multiplanar</i></p> <ul style="list-style-type: none"> - Quadriceps strength \geq 85% - Effusion \leq trace - Hop testing \geq 85% (appendix 7) - Completion of running progression - Completion of Stage 1 Sprint Progression <p>No apprehension with light agilities</p>

<p>Home Exercise Program Recommendations: Individualized based on specific sport and patient needs. Ensure the demand is sufficient to improve the working capacity with sport specific skills. Ex: Soccer player (not fully-inclusive)</p>	
<p><i>Strength Training (2-3x per week):</i></p> <ul style="list-style-type: none"> - Unilateral and bilateral knee extension, 5 x 5 @ 60-85% 1-RM - Kettlebell/dumbbell squats, 3 x 12 - Single leg squat with heel raises, 3 x 12 - Single leg RDLs with kettlebell, 3 x 12 - Rearfoot elevated split squats with dumbbells, 3 x 10 - Nordic hamstring curls, 3 x 7 - Copenhagen planks, 3 x 30" 	<p><i>Aerobic Conditioning (3-4x per week):</i></p> <ul style="list-style-type: none"> - Aerobic training on level ground or treadmill, 20-30 minutes continuous - Tempo runs on track or soccer field - Speed ladders on sport specific surface (e.g. grass, turf) - Short burst acceleration/deceleration cone drills with soccer ball



Transitional Phase IV (months 6-9)	
Phase Goals: - Sport specific skill acquisition - Restoration of conditioning level to pre-injury level	Milestones: - Quad strength \geq 90-100% of uninjured - Hop testing \geq 90% - KOS-ADLS \geq 90% - ACL RSI \geq 70% - No effusion or pain with running, sprinting or agilities
Treatment Strategies:	
Total Visits: 31-46 visits	Muscle Performance: - High intensity power training and maximal effort strength training
PT Frequency: 1-2x per month	Agility Training: - 80-100% intensity, reactive, unpredictable and sport specific Sport Specific Training: - Individualized to sport/position, incorporate sport specific equipment and environments as able
HEP Frequency: 3-4x per week	Dynamic Anaerobic/Aerobic Training: - Maximal effort sled push/pull and circuit training
Supervised by ATC or Strength Coach if able	Stage 2 Sprint Progression Criteria: - Quadriceps strength \geq 90% - Effusion \leq trace - Hop testing \geq 90% (Appendix 7) - Completion Stage 1 sprint progression - No apprehension with moderate to high level agilities Appendix 8 for Stage 2 Sprint Progression
	Return to Cutting and Pivoting Criteria: - Quadriceps strength \geq 90% - Effusion \leq trace - Hop testing \geq 90% (Appendix 7) - No apprehension with moderate to high level agilities - Completion of Stage 1 and 2 sprint progression Appendix 1 for considerations specific to allografts
	Stage 3 Sprint Progression Criteria: - Quadriceps strength \geq 90% - Effusion \leq trace - Hop testing \geq 90% (Appendix 7) - No apprehension with moderate to high level agilities - Completion of Stage 2 sprint progression Appendix 8 for Stage 3 Sprint Progression



Return to Sport Phase V (months 9-12)	
<p>Phase Goals:</p> <ul style="list-style-type: none"> - Sport specific skill acquisition - Build confidence during play with opponents - Continuation of Secondary Prevention 	<p>Milestones:</p> <ul style="list-style-type: none"> - At least 9 months post-op (allografts 12+ months) - Quad strength \geq 90% of uninjured (level 1 athletes \geq 100%) - Hop testing \geq 90% - KOS-ADLS \geq 90% - ACL RSI \geq 80% - IKDC > 76 - Marx Activity Scale < 9
Treatment Strategies:	
<p>Total Visits: 35-50 visits</p> <p>PT Frequency: 1-2x per month or until all RTS criteria is met Injury</p> <p>Prevention HEP Frequency: 2-3x per week</p>	<p>Return to Competition Progression:</p> <ul style="list-style-type: none"> - Non-contact practice - Small sided contact practices (1v1, 2v2, 3v3) - Full Practice - Return to competition with restricted workload - Return to competition unrestricted <p>*All without apprehension, pain, instability, effusion or compensations</p> <hr/> <p>ACL Secondary Prevention Program:</p> <ul style="list-style-type: none"> - 2x per week moving forward - Maintain quadriceps strength and periodically assess with 1-RM knee extension strength test (pre/post season) - See Knee Injury Prevention CPG for guidelines and video examples - Consider long term implementation of Copenhagen planks and Nordic hamstring curls for lower extremity injury risk reduction strategies <p>If functional ACL Brace is used: may discontinue use after 1 year</p> <hr/> <p>Additional Consideration:</p> <ul style="list-style-type: none"> - No effusion, pain or apprehension with sport specific training and practice progressions - Return to pre-injury conditioning level - Minimal to no dynamic knee valgus with jumping and landing - Hamstring/quadriceps ratio - Vertical hop symmetry assessment



Procedure:	Rehab Modification:
Patellar Tendon Autograft (BPTB):	<ul style="list-style-type: none"> - Be aware of patellofemoral forces and possible irritation during progressive resistive exercises (PRE's) - Treat anterior knee pain PRN with noxious e-stim, patellar taping; consider modifications of strength program (treat as tendinopathy using Pain Monitoring Model) - Consider alteration of knee flexion angle to most comfortable between 45°-60° for MVIC and NMES treatments - Initial Burst test at 12 weeks if no pain < 5/10
Hamstring Tendon Autograft:	<ul style="list-style-type: none"> - Begin isometric knee flexion no earlier than week 6 - Begin dynamic knee flexion no earlier than week 8, dynamic knee flexion with load and pain free 0-90° week 8-12 weeks - No hamstring restrictions beyond 12 weeks - Delay plyometrics until 16 weeks
Quad Tendon Autograft:	<ul style="list-style-type: none"> - Similar to BPTB and tendinopathy protocols, slower to regain quad strength - Modify hip angle (minimize hip flexion) to focus on strengthening of the rectus femoris
Allografts:	<ul style="list-style-type: none"> - Slower graft incorporation, therefore, slower progression to running, jumping, cutting and pivoting - Ensure all objective criteria is satisfied prior to progression - Delay return to level 1 sport until all criteria met and 1 year post-operative
Partial Meniscectomy:	<ul style="list-style-type: none"> - No modifications required; progress per patient tolerance and protocol
Meniscal Repair:	<ul style="list-style-type: none"> - Simple Repair: <ul style="list-style-type: none"> • WBAT in brace locked in full extension or knee immobilizer immediately for 4 weeks • ROM progression: 0-90° by week 2, progress as tolerated thereafter - Complex or Root Repair: <ul style="list-style-type: none"> • NWB in knee immobilizer for 6 weeks • ROM progression: 0-90° by week 2, progress as tolerated thereafter • Progress to full weight bearing by week 9 • Initiate CKC PRE at week 9 • Weight bearing flexion limited 0-45° weeks 8-12, 0-70° through week 16 • No isolated hamstring strengthening for 16 weeks - Resume standard ACL protocol after 16 weeks - Seated isokinetic and multi angle quadriceps isometric can substitute for weight-bearing exercises early on



Concomitant Abrasion Chondroplasty:	- WBAT with axillary crutches 3-5 days No modifications required, progress per patient tolerance and protocol
Concomitant Microfracture:	- NWB 2-4 weeks with axillary crutches - No weightbearing activities in treatment for 4 weeks <i>*Consider location and size of lesion for exercise specific alterations*</i>
Chondral Repair (OATS, ACI, MACI):	- Follow procedure specific protocol if done concomitantly
Meniscal Transplantation:	- Follow procedure specific protocol if done concomitantly
Concomitant MCL Injury:	- Restrict motion to sagittal plane until week 4-6 to allow healing of MCL - Perform PRE's with tibia in internal rotation during early post-op period to decrease MCL stress - Consider brace for exercise and periods of activity if severe sprain and/or patient has pain - Post-operative concomitant MCL Repair: <ul style="list-style-type: none"> • PWB locked in extension for 1-2 weeks • Unlock brace with weightbearing at week 2-6 and wean from brace and assistive devices • ROM restrictions: flexion ROM 0-90°, progress as tolerated thereafter • Avoid exercises resulting in valgus stress at knee
LCL Injury:	- Follow LCL rehabilitation guidelines (Not ACL protocol)
PCL injury:	- Follow PCL rehabilitation guidelines (Not ACL protocol)
Posterolateral Corner Repair:	- Minimize external rotation torques and varus stress 6-8 weeks - Avoid hyper-extension - No resisted knee flexion for 12 weeks
ACL Revision:	- Delay progression of running, hop testing and agility drills by 4 weeks - Crutches and immobilizer will be used 2 weeks following surgery - Delay return to sport beyond 12 months



Appendix 2: Measuring Effusion: Sweep Test	
Instructions:	<ol style="list-style-type: none"> 1. Milk out swelling distal to proximal several times along the medial aspect of the knee 2. Sweep proximal to distal on the lateral aspect of knee 3. View the medial sulcus for return of swelling
Grade Zero:	None
Grade Trace:	Small amount returns
Grade 1+:	Can milk out the swelling and it does not return on its own but returns with lateral sweep
Grade 2+:	Can milk out the swelling and it returns immediately to fill the pouch
Grade 3+:	Cannot milk swelling out
Rules:	<ol style="list-style-type: none"> 1. Patients should not progress in their exercise program when the effusion is > 1+ 2. When patients are holding anything above a 2+ for prolonged periods, contact MD 3. Any drastic changes of 2 grades or appearance of effusion when it was absent, decrease activity and gradually reintroduce activity when possible
<small>Modified with permission from JOSPT. Adams D, Logerstedt D, Hunter-Giordano A, Axe MJ, Snyder-Mackler L. Current concepts for anterior cruciate ligament reconstruction: A criterion-based rehabilitation progression. <i>J Orthop Sports Phys Ther.</i> 2012;42(7):601-614. doi:10.2519/jospt.2012.3871</small>	

Appendix 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 same level that led to soreness
Soreness during warm-up that goes away but redevelops during session	2 day off, drop down 1 level
Soreness the day after lifting (not muscular soreness)	1 day off, do not advance program to next level
No Soreness	Advance 1 level per week or as instructed by healthcare professional
<small>Modified with permission from JOSPT. Adams D, Logerstedt D, Hunter-Giordano A, Axe MJ, Snyder-Mackler L. Current concepts for anterior cruciate ligament reconstruction: A criterion-based rehabilitation progression. <i>J Orthop Sports Phys Ther.</i> 2012;42(7):601-614. doi:10.2519/jospt.2012.3871</small>	

Appendix 4: Non-weight Bearing Quadriceps Exercise Recommendations	
All exercises completed 90-0°:	
Weeks 0-2	LAQ: No/light resistance: 10-15 reps, 2-3 sets, tempo 3-1-3
Weeks 2-3	LAQ: Heavy cuff weights/Knee Extension Machine, 10-15 reps, 2-3 sets, tempo 3-1-3
Weeks 4-6	LAQ: Knee extension machine, 15-20 reps, 2-3 sets, tempo 3-1-3
Weeks 7-9	Knee extension machine: single leg/eccentrics, 15-20 reps, 2-3 sets, tempo 3-1-3
Weeks 10-12	Knee extension machine: single leg/eccentrics, 8-12 reps @ 60-85% 1 RM, 2-3 sets
Weeks 13-16+	Knee extension machine: single leg/eccentrics, 5-8 reps, 4-5 sets, 75-90% 1 RM
May consider BFR Training to volitional failure if higher loading is not tolerated well	
Progress load and exercise volume based on knee joint effusion and soreness rules	



Appendix 5: Neuromuscular Electric Stimulation for Quadriceps Strengthening

NMES Guidelines:

1. Electrodes placed over proximal lateral quadriceps and distal medial quadriceps (modify distal electrode placement until portal is healed)
2. Stimulation parameters: 400 micro sec pulse width, 75 pulses/sec, 2 sec. ramp up, 12 sec. on, 50 sec. rest, intensity to max tolerable [**at least 50% MVIC**] 15 contractions per session, 3 sessions per week until quadriceps strength MVIC is 80% of uninjured
3. Stimulation performed **isometrically** at **60°** (if patellar or quad tendon graft, consider beginning NMES at 45° knee flexion and progressing angle to 60° as tendon pain subsides)



Maximum Volitional Isometric Contraction (MVIC): Patient is asked to volitionally extend the involved leg as hard as possible while knee is maintained isometrically at 60° knee flexion

- Side to side comparison: $(\text{involved/uninvolved} \times 100 = \% \text{ MVIC})$
- NMES dosed at $\geq 50\%$ of MVIC



Appendix 6: Running Progression

	Treadmill	Track
Level 1	0.1 mile walk / 0.1 mile jog, repeat 10 times	Jog straights / walk curves (2 miles)
Level 2	0.1 mile walk / 0.2 mile jog - 2 miles total	Jog straights / jog 1 curves every other lap (2 miles)
Level 3	0.1 mile walk / 0.3 mile jog - 2 miles total	Jog straights / jog 1 curve every lap (2 miles)
Level 4	0.1 mile walk / 0.4 mile jog - 2 miles total	Fast walk 1 ¾ lap / walk curve (2 miles)
Level 5	Jog full 2 miles	Jog full 2 miles
Level 6	Increase workout to 2 ½ miles	Increase workout to 2 ½ miles
Level 7	Increase workout to 3 miles	Increase workout to 3 miles
Level 8	Alternate between running/jogging every ¼ mile	Increase speed on straights / jog curves

Instructions:

- Mandatory 2-day rest between workouts for first two week
- Do not advance more than 2 levels per week
- Two days rest mandatory between levels 1, 2, and 3 workouts
- One day rest mandatory between levels 4-8 workouts

Soreness Rules:

- If sore during warm-up, take 2 days off and drop down 1 level
- If sore during workout, take 1 day off and drop down 1 level
- If sore after workout, stay at same level

Specific Considerations:

- Non-endurance athletes: must successfully complete level 4 of progression before advancement to sprinting

Modified with permission from JOSPT. Adams D, Logerstedt D, Hunter-Giordano A, Axe MJ, Snyder-Mackler L. Current concepts for anterior cruciate ligament reconstruction: A criterion-based rehabilitation progression. *J Orthop Sports Phys Ther.* 2012;42(7):601-614. doi:10.2519/jospt.2012.3871



Appendix 7: Hop Testing

Purpose: Objective function testing of the lower extremity aids in determining functional limitations of the knee joint during sports activities.

Selection of Questions:
Four one-legged function tests comprise the objective function testing (completed in order):

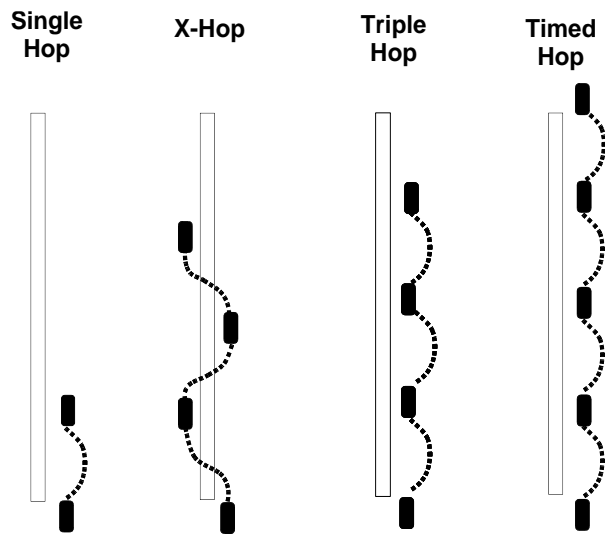
1. Single hop (distance)
2. Cross-over hop (distance)
3. Triple hop (distance)
4. Timed hop

Complete one warm up trial on each limb, beginning with the uninvolved side

Materials Needed:

1. One stopwatch
2. One tape measure
3. Standard marking tape

Test Descriptions:



1. Single hop (distance)	The distance a patient travels in one hop on a single leg is recorded. Each patient is allowed one trial for each leg, and then performs two hops per leg.
2. Cross-over hop (distance)	A six-meter line six inches wide is marked with tape. The patient performs three hops on one leg, crisscrossing the line with each hop. Each test is completed twice on each leg, with the total distance hopped measured.
3. Triple hop (distance)	The patient performs a series of three hops on one leg, with the total distance hopped measured. The test is performed twice on each leg.
4. Timed hop (6 m)	Measure a distance of six meters, marking start and finish lines with tape. A technician stands at the finish line to time the subjects with a stopwatch. At the word "go", the patient begins a series of one-legged hops from the starting line to the finish line. Patients are encouraged to use large forceful hopping motions, not a series of small hops, to complete the course. Each patient completes a slow trial on each leg. A series of two tests per leg are then completed. Two tests are first completed on the non-involved leg, followed by two tests on the involved leg.
Interpretation:	The mean is taken from the two tests performed on each leg. Then, the percent deficit between limbs is calculated.

Noyes FR, Barber SD, Mangine RE. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. *Am J Sports Med.* 1991;19(5):513-518. doi:10.1177/036354659101900518



Appendix 8a: Criteria-based Return to Sprinting Progression			
Stage 1: 50% Intensity (1:3 work to rest ratio)			
Objective: Build work capacity for anaerobic conditioning/endurance			
Step 1	Step 2	Step 3	Step 4
20 yd x 3 untimed	20 yd x 4 untimed	20 yd x 3	20 yd x 3
40 yd x 2 untimed	40 yd x 3 untimed	40 yd x 4	40 yd x 4
60 yd x 2 untimed	60 yd x 2 untimed	60 yd x 2	60 yd x 2
80 yd x 2 untimed	80 yd x 2 untimed	80 yd x 2	80 yd x 2
100 yd x 1 untimed	100 yd x 1 untimed	100 yd x 1	100 yd x 2
80 yd x 2 untimed	80 yd x 2 untimed	80 yd x 2	80 yd x 1
60 yd x 2 untimed	60 yd x 2 untimed	60 yd x 2	60 yd x 2
40 yd x 2 untimed	40 yd x 3 untimed	40 yd x 4	40 yd x 4
20 yd x 3 untimed	20 yd x 4 untimed	20 yd x 3	20 yd x 3
19 runs @ 940 yd	23 runs @ 1060 yd	23 runs @ 1100 yd	23 runs @ 1120 yd
Qualifier: Gradual build in acceleration from starting line with slow, controlled deceleration beyond end line			
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Appendix 8b: Criteria-based Return to Sprinting Progression			
Stage 2: 75% Intensity (1:5 work to rest ratio)			
Objective: Speed development, improve technique and build repeated sprint ability			
Step 1	Step 2	Step 3	Step 4
20 yd x 3	20 yd x 3	20 yd x 2	20 yd x 2
40 yd x 2	40 yd x 2	40 yd x 2	40 yd x 2
60 yd x 2	60 yd x 1	60 yd x 1	60 yd x 2
80 yd x 1	80 yd x 1	80 yd x 1	80 yd x 1
100 yd x 1	100 yd x 1	100 yd x 1	60 yd x 2
80 yd x 1	80 yd x 1	80 yd x 1	40 yd x 2
60 yd x 2	60 yd x 1	60 yd x 1	20 yd x 2
40 yd x 2	40 yd x 2	40 yd x 2	
20 yd x 3	20 yd x 3	20 yd x 2	
17 runs @ 780 yd	15 runs @ 660 yd	13 runs @ 620 yd	13 runs @ 560 yd
Qualifier: Rapid build in acceleration from starting line with moderate deceleration beyond end line			
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Appendix 8c: Criteria-based Return to Sprinting Progression			
Stage 3: 90-100% Intensity (1:7 work to rest ratio)			
Objective: Achieve maximum effort. Work:rest ratio should replicate sport demands in step 3 and 4			
Step 1	Step 2	Step 3	Step 4
20 yd x 6	10 yd x 3	10 yd x 3	10 yd x 2
40 yd x 2	20 yd x 4	20 yd x 3	20 yd x 3
60 yd x 1	40 yd x 2	30 yd x 2	30 yd x 2
40 yd x 2	60 yd x 1	40 yd x 2	40 yd x 1
20 yd x 6	40 yd x 2	60 yd x 1	60 yd x 1
10 yd x 3	30 yd x 1	30 yd x 2	40 yd x 1
	20 yd x 4	20 yd x 3	30 yd x 2
	10 yd x 2	10 yd x 3	20 yd x 3
*Full subjective recovery	*Full subjective recovery		10 yd x 2
20 runs @ 490 yd	19 runs @ 460 yd	19 runs @ 440 yd	17 runs @ 420 yd
Qualifier: Maximal build in acceleration from starting line with moderate deceleration beyond end line			
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