ANTERIOR CRUCIATE LIGAMENT (ACL) RECONSTRUCTION: QUADRICEPS TENDON AUTOGRAFT

Background

The following anterior cruciate ligament (ACL) reconstruction rehabilitation protocol is specific to patients with a quadriceps tendon autograft. If a hamstring autograft was used, please refer to the "Anterior Cruciate Ligament (ACL) Reconstruction: Hamstring Autograft" protocol on the Ohio State Sports Medicine website. If a bone tendon bone autograft was used, please refer to the "Anterior Cruciate Ligament (ACL) Reconstruction: Bone Tendon Bone Autograft" protocol on the Ohio State Sports Medicine website.

The rehabilitation recommendations below are based upon the guidance of content experts, evidence-based practice and the Multicenter Orthopaedic Outcomes Network (MOON) group. Progression through each phase is based on the patient demonstrating readiness by achieving functional criteria rather than the time elapsed from surgery. The times frames identified after each phase are approximate times for the average patient, NOT guidelines for progression.

Disclaimer

Progression is time and criterion-based, dependent on soft tissue healing, patient demographics and clinician evaluation. If you are working with an Ohio State Sports Medicine patient and questions arise, please contact the author by calling our office at (614) 293-2385.

Summary of Recommendations

Precautions	1. No testing of repaired or reconstructed ligaments (Lachman, Anterior/Posterior Drawer, Varus/Valgus Stress) prior to 12 WEEKS post-operative 2. No loaded open kinetic chain knee extension beyond 45 degrees x 8 WEEKS 3. Meniscus Repair: a. No forced flexion ROM beyond 90º x4 WEEKS b. No CKC exercises >90º x *8 WEEKS* c. PWBing x 4 weeks for concomitant root, radial and/or horizontal cleavage meniscus repairs only i. All other types of meniscus repairs will be FWBing ii. *Please refer to the "post-op plan" section of the operative note for clarification*
Outcome Tools	Collect the Lower Extremity Functional Scale (LEFS) at each visit Consider collecting one of the following outcome tools at initial evaluation, monthly and discharge. Be consistent with which outcome tool is collected each time. 1. IKDC 2. KOOS *You may choose to include ACL-RSI, Tegner or other questionnaires specific to your patient's needs*.
Strength Testing	1. Isometric testing anytime- fixed at 90º 2. Isokinetic testing no earlier than 12 weeks
Criteria to Discharge Assistive Device	1. ROM: Full active knee extension equivalent to healthy, contralateral limb; no pain on passive overpressure 2. Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 supine SLR without quad lag 3. Effusion: ≤1+ is preferred (2+ acceptable if all other criteria are met) 4. Weight Bearing: Demonstrates pain-free ambulation without visible gait deviation
Criteria to Initiate Running and Jumping	1. ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb 2. Strength: Isokinetic testing 80% or greater for hamstring and quad at 60º/sec and 300º/sec ***(Appendix D)*** 3. Effusion: ≤ 1+ 4. Weight Bearing: normalized gait and jogging mechanics 5. Neuromuscular Control: Pain-free hopping in place
Criteria for Return to Sport	1. ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb 2. Strength: Isokinetic testing 90% or greater for hamstring and quad at 60º/sec and 300º/sec ***(Appendix D)*** 3. Effusion: No reactive effusion ≤ 1+ with sport-specific activity 4. Weight Bearing: normalized gait and jogging mechanics 5. Neuromuscular control: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements 6. Functional Hop Testing: LSI ≥ 90% for all tests ***(Appendix E)*** 7. Physician Clearance

RED/YELLOW FLAGS

Red flags are signs/symptoms that require immediate referral for re-evaluation. Yellow flags are signs/symptoms that require modification to plan of care.

Red Flags	• Signs of DVT *(Refer directly to ED)*
	  ○ Localized tenderness along the distribution of deep venous system
	  ○ Entire LE swelling
	  ○ Calf swelling >3cm compared to asymptomatic limb
	  ○ Pitting edema
	  ○ Collateral superficial veins
	• Lack of full knee extension by 4 weeks *(Refer to surgeon for re-evaluation)*
	• Mechanical block or clunk *(Refer to surgeon for re-evaluation)*

Yellow Flags	• Persistent reactive pain or effusion following therapy or ADLs ○ *Decrease intensity of therapy interventions, continue effusion management and provide patient education regarding activity modification until reactive symptoms resolve*

Protection Phase (Post-ACLR – 4 weeks)

Appointments	• Goal: Restore ROM, minimize effusion and pain. • Post-operative evaluation should be performed 3-5 days following surgery. Follow-up appointments 1-2x per week, depending on progression towards goals.

Precautions	a. No testing of repaired or reconstructed ligaments (Lachman, Anterior/Posterior Drawer, Varus/Valgus Stress) prior to 12 WEEKS post-operative
	b. No loaded open kinetic chain knee extension beyond 45 ° x 8 WEEKS
	4. Meniscus Repair:
	  d. No forced flexion ROM beyond 90º x4 WEEKS
	  e. No CKC exercises >90º x *8 WEEKS*
	  f. <u>PWBing x 4 weeks for concomitant root, radial and/or horizontal cleavage meniscus repairs only</u>
	  i. All other types of meniscus repairs will be FWBing
	  ii. *Please refer to the "post-op plan" section of the operative note for clarification*

Pain and Effusion	≤2+ (using Modified Stroke Test) • Effusion management strategies: cryotherapy and compression (ie. Donut, ace wrap) and limited WB therapeutic exercise as appropriate
ROM	**Strong emphasis on patellar mobilizations (superior/inferior > medial/lateral) to regain full knee ROM** <u>Extension:</u> Emphasis on achieving full knee extension immediately following surgery. If full extension is not achieved by 4 weeks, contact surgeon regarding ROM concerns. Utilize low load, long duration stretching **(Appendix A)** <u>Flexion:</u> No forced flexion past 90º for all meniscus repairs. ACLR and meniscectomy are able to push for symmetrical flexion as appropriate.

Therapeutic Exercise	• Emphasis on quad activation without gluteal co-contraction • Restore patellar mobility • Symmetrical ROM • Decrease effusion • Ambulation with appropriate joint loading and without obvious gait deviation
Suggested Interventions	• Extension ROM: bag hangs or prone hangs *(Appendix A)* • Flexion ROM: heel slides, wall slides, upright bike • Patellar mobilization: superior, inferior, medial, lateral • Quad Isometrics; SLR 4-way • TKE: prone and standing • Prone hamstring curls • Weight shifting, SL balance • Neuromuscular re-education using electrical stimulation (NMES) at 60º knee flexion *(Appendix B)*
NMES Parameters *(Appendix B)*	• NMES pads are placed on the proximal and distal quadriceps • Patient: Seated with the knee in at least 60º flexion, shank secured with strap and back support with thigh strap preferred. The ankle pad/belt should be two finger widths superior to the lateral malleoli • The patient is instructed to relax while the e-stim generates at least 50% of their max volitional contraction against a fixed resistance OR maximal tolerable amperage without knee joint pain • 10-20 seconds on/ 50 seconds off x 15 min
Criteria to Discharge Assistive Device	1. ROM: Full active knee extension; no pain on passive overpressure 2. Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 supine SLR without quad lag 3. Effusion: ≤ 1+ is preferred (2+ acceptable if all other criteria are met) 4. Weight Bearing: Demonstrates pain-free ambulation without visible gait deviation
Criteria to Progress to Early Loading Phase	**Goals: (These do not limit progression to next phase; however, should be addressed with interventions)** ROM: ≥ 0-120 degrees Strength: Quadriceps set with normal superior patellar translation, SLR x 10 seconds without extensor lag Effusion: ≤ 2+ with Modified stroke test Weight Bearing: Able to tolerate CKC therex program without increased pain and ≤ 2+ effusion

Early Loading Phase (4-8 weeks)

Appointments	• Goal: to improve LE loading symmetry, increase strength and normalize gait mechanics. • 1-2 visits per week with emphasis on HEP compliance (2-3 days per week outside of therapy).
Precautions	**If full AROM knee extension is not achieved by 4 weeks, contact surgeon** Open Chain knee extension: • Initiate unresisted LAQ at 4 weeks (partial → full range) • Initiate multi-angle isometrics (from 90-60º) at 4 weeks • Begin isotonic open chain knee extensions through protected ROM (90-45°) at 6 weeks
Pain and Effusion	Cryotherapy/compression as needed for reactive effusion. Patellar taping and/or Cho-Pat strap to reduce PF symptoms if present
ROM	• Monitor and progress knee ROM, patellar mobility, and LE flexibility • Continued emphasis on end-range ROM • Continue bike for ROM and warm up

Suggested Interventions and timelines	• Multi-angle knee isometrics from 90-60º
	• Initiate open chain knee extension exercises
	  ○ Initiate unresisted LAQ at 4 weeks (partial → full range)
	  ○ Begin isotonic open chain knee extensions through protected ROM (90-45°) at 6 weeks
	• Progress WB quadriceps exercises with emphasis on proper LE mechanics
	• Hamstring curls (prone, machine or physioball)
	• Progress gluteal and lumbopelvic strength and stability
	• Progress single leg balance
	• Endurance: low impact - treadmill walking, stepper, elliptical (6 weeks)
	• NMES (see parameters in week 1-4)

Criteria to d/c NMES	• <20% quadriceps deficit on isometric testing **OR- If a Biodex machine is not available:** 1. 10 SLR without quad lag 2. Normal gait 3. 10 heel taps to 60 degrees with good quality 4. 10 rep max on LP and similar effort bilaterally 5. Inability to break quad MMT
Criteria to Progress to Strength and Power Phase	1. ROM: Maintain full, pain free AROM including PF mobility 2. Effusion: ≤ 1+ 3. Strength: See criteria to discharge NMES 4. Weight Bearing: Able to tolerate therapeutic exercise program without increased pain or >1+ effusion 5. Neuromuscular Control: Demonstrates proper lower extremity mechanics with all therapeutic exercises (bilaterally)

Strength and Power Phase (8-12 weeks)

Appointments	• Goal to increase lower extremity strength and power. • 1-2 visits per week with emphasis on patient compliance with resistance training as part of HEP (2-3 days per week outside of therapy).
Precautions	Open Chain knee extension: resisted open chain knee extension (protected ROM →full ROM)
Pain and Effusion	Cryotherapy/compression as needed for reactive effusion. Patellar taping and/or Cho-Pat strap to reduce PF symptoms if present
ROM	• Monitor and progress knee ROM, patellar mobility, and LE flexibility • Consider higher level warm ups, including bike sprints or versaclimber • Continue aggressive techniques to achieve/maintain full knee extension if necessary (i.e. weighted bag hang) as needed • If full AROM knee extension is not achieved by 4 weeks, contact surgeon regarding ROM concerns.

Suggested Interventions and timelines	• Multi-angle knee isometrics from 90-0º
	• Progress isotonic open chain knee extensions through full range (90-0º)
	• Continue isolated hamstring interventions
	  ○ RDL
	  ○ Nordic hamstring curls
	• Progress gluteal and lumbopelvic strength and stability
	• Progress single leg balance
	• Initiate PWB plyometrics on shuttle (8-10 weeks)
	• NMES if appropriate (see parameters in week 1-4)

Criteria to initiate Running and Jumping	1. ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb 2. Strength: Isokinetic testing 80% or greater for hamstring and quad at 60º/sec and 300º/sec ***(See Appendix C and D)*** 3. Effusion: ≤ 1+ 4. Weight Bearing: normalized gait and jogging mechanics 5. Neuromuscular Control: Pain-free hopping in place
Criteria to Progress to Return to Function Phase	6. ROM: Maintain full, pain free AROM including PF mobility 7. Effusion: ≤ 1+ 8. Strength: Isometric or isokinetic quadriceps and hamstrings strength >/= 80% 9. Weight Bearing: Able to tolerate therapeutic exercise program, including jogging progression, without increased pain or >1+ effusion 10. Neuromuscular Control: Demonstrates proper lower extremity mechanics with all therapeutic exercises (bilaterally) 11. Outcome Tools: ≥ 7/10 on #10 IKDC Questionnaire

Return to Function Phase (12 weeks-Return to Sport)

Appointments	Increased frequency from previous stage to 1-2x per week when appropriate to initiate plyometric training and return to running program.
Precautions	Criteria to initiate hopping • Full, pain free ROM • ≤ 1+ effusion • ≥ 7 /10 on #10 IKDC Questionnaire • ≥ 80% isokinetic strength symmetry (hamstrings and quadriceps) OR ≥ 80% limb symmetry on acceptable isokinetic alternative ***(See Appendix D)*** Criteria to initiate jogging (in addition to above criteria) • Hop downs with appropriate landing mechanics • Audible rhythmic strike patterns and no gross visual compensation
Pain and Effusion	Effusion may increase with increased activity, ≤1+ and/or non-reactive effusion for progression of plyometrics
ROM	Full, symmetrical to contralateral limb, and painfree with overpressure
Therapeutic Exercise	• Performance of the quadriceps, hamstrings and trunk dynamic stability • Muscle power generation and absorption via plyometrics • Sport- and position-specific activities • Begin agility exercises between 50-75% effort (utilize visual feedback to improve mechanics as needed) • Advance plyometrics: Bilateral to single leg, progress by altering surfaces, adding ball toss, 3D rotations, etc.
Suggested Interventions	Therapeutic Exercise/Neuromuscular Re-education • Squats, leg extension, leg curl, leg press, deadlifts, lunges (multi-direction), crunches, rotational trunk exercises on static and dynamic surfaces, monster walks, PWB to FWB jumping • Single-leg squats on BOSU with manual perturbation to trunk or legs, Single-leg BOSU balance, single-leg BOSU Romanian deadlift Agility • Side shuffling, Carioca, Figure 8, Zig-zags, Resisted jogging (Sports Cord) in straight planes, backpedaling Plyometrics • Single-leg hop downs from increasing height (up to 12” box), Single-leg hop-holds, Double and single-leg hopping onto unstable surface, Double and single-leg jump-turns, Repeated tuck jumps
Criteria for Return to Sport	1. ROM: full, pain free knee ROM, symmetrical with the uninvolved limb 2. Strength: Isokinetic testing 90% or greater for hamstring and quad at 60º/sec and 300º/sec 3. Effusion: No reactive effusion ≥ 1+ with sport-specific activity 4. Weight Bearing: normalized gait and jogging mechanics 5. Neuromuscular control: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements 6. Functional Hop Testing: LSI 90% or greater for all tests ***(Appendix E)*** 7. Physician Clearance

Appendix A: Bag Hang

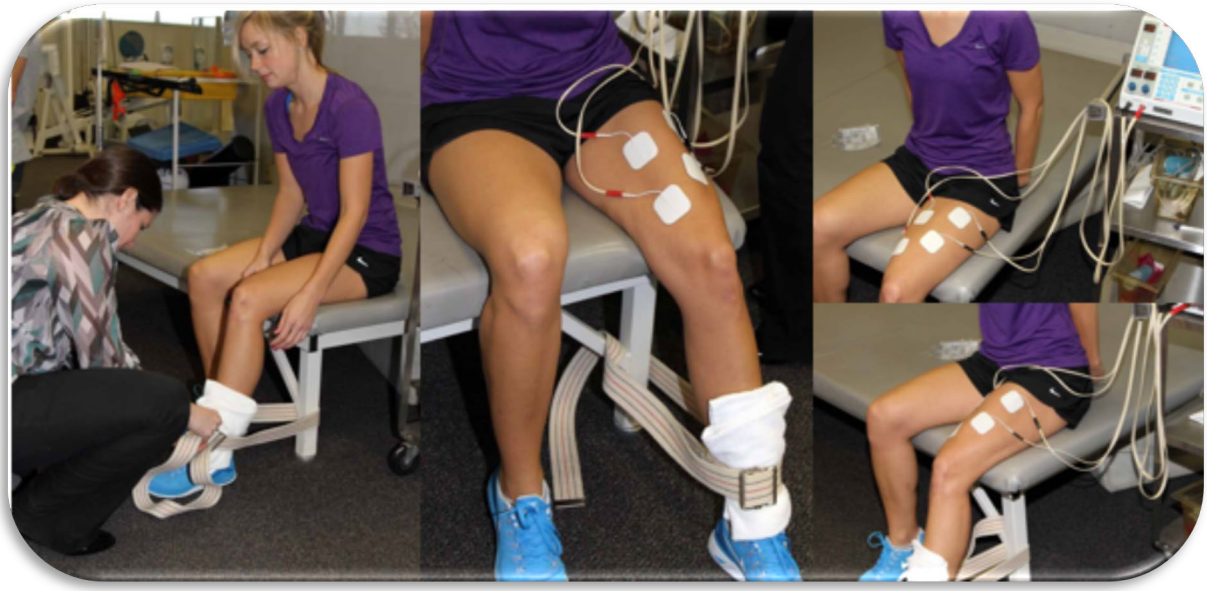
Emphasis on low load, long duration stretching

- *Goal: 60 minutes of bag hang time total per day.*
- *Ideally: 4x15 minutes (or greater) per day*

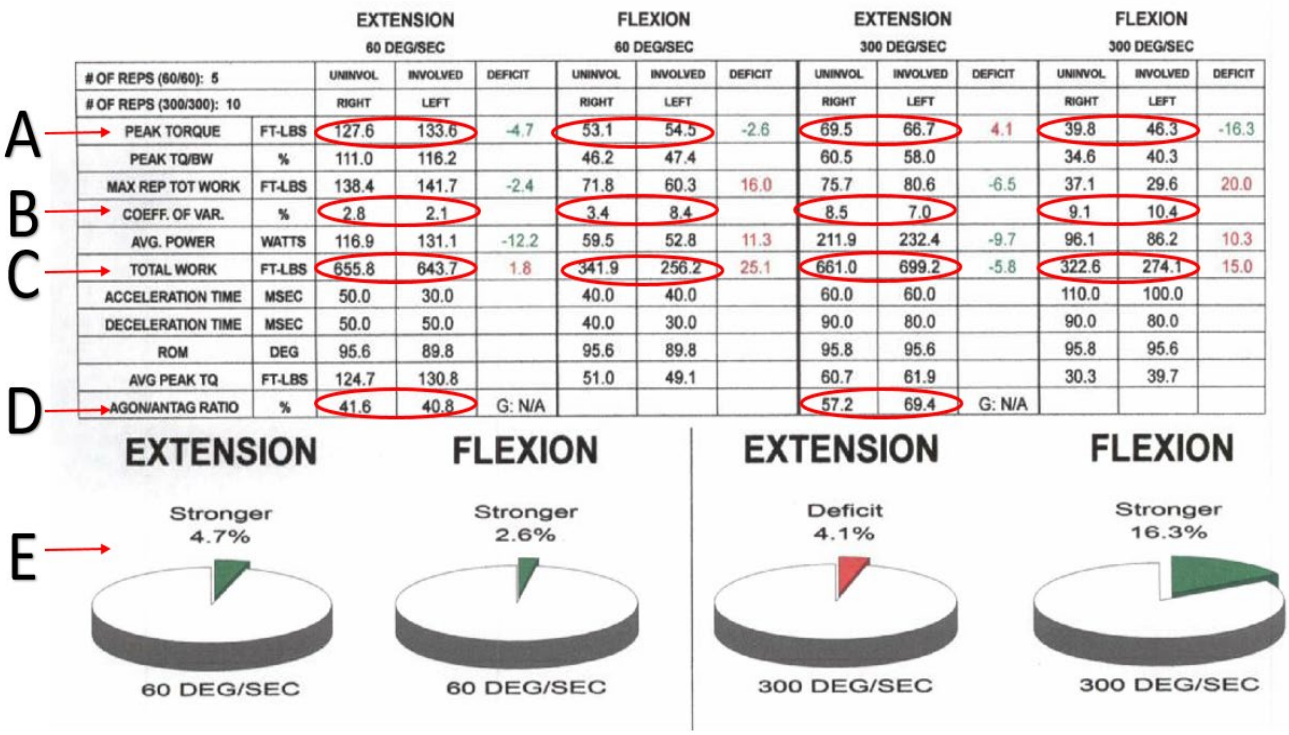
Appendix B: NMES Set Up

2 or 4 pad set-up is appropriate

- NMES pads are placed on the proximal and distal quadriceps
- Patient: Seated with the knee in at least 60º flexion, shank secured with strap and back support with thigh strap preferred. The ankle pad/belt should be two finger widths superior to the lateral malleoli
- The patient is instructed to relax while the e-stim generates at least 50% of their max volitional contraction against a fixed resistance OR maximal tolerable amperage without knee joint pain
- 10-20 seconds on/ 50 seconds off x 15 min



Appendix C: Isokinetic Data Interpretation



		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC			EXTENSION 300 DEG/SEC			FLEXION 300 DEG/SEC		
# OF REPS (60/60): 5		UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT
# OF REPS (300/300): 10		RIGHT	LEFT		RIGHT	LEFT		RIGHT	LEFT		RIGHT	LEFT	
A → PEAK TORQUE	FT-LBS	127.6	133.6	-4.7	53.1	54.5	-2.6	69.5	66.7	4.1	39.8	46.3	-16.3
PEAK TQ/BW	%	111.0	116.2		46.2	47.4		60.5	58.0		34.6	40.3	
MAX REP TOT WORK	FT-LBS	138.4	141.7	-2.4	71.8	60.3	16.0	75.7	80.6	-6.5	37.1	29.6	20.0
B → COEFF. OF VAR.	%	2.8	2.1		3.4	8.4		8.5	7.0		9.1	10.4	
AVG. POWER	WATTS	116.9	131.1	-12.2	59.5	52.8	11.3	211.9	232.4	-9.7	96.1	86.2	10.3
C → TOTAL WORK	FT-LBS	655.8	643.7	1.8	341.9	256.2	25.1	661.0	699.2	-5.8	322.6	274.1	15.0
ACCELERATION TIME	MSEC	50.0	30.0		40.0	40.0		60.0	60.0		110.0	100.0	
DECELERATION TIME	MSEC	50.0	50.0		40.0	30.0		90.0	80.0		90.0	80.0	
ROM	DEG	95.6	89.8		95.6	89.8		95.8	95.6		95.8	95.6	
AVG PEAK TQ	FT-LBS	124.7	130.8		51.0	49.1		60.7	61.9		30.3	39.7	
D → AGON/ANTAG RATIO	%	41.6	40.8	G: N/A				57.2	69.4	G: N/A			

		Definition	Clinical Impact	What to do
A	Peak Torque (ft-lbs)	Peak torque during repetitions	Symmetry criteria (see 'E'- this is the data represented in pie charts)	If <80%; continue unilateral, high resistance strength training
B	Coefficient of Variance (%)	Between repetition variability	Goal: < 15%	If >15%, consider retest
C	Total Work (ft-lbs)	Torque over all repetitions	Possible indicator of fatigue	If >10%; consider high volume training
D	Agonist/Antagonist Ratio (%)	Hamstring/Quadriceps Ratio	Goal: >60%	<60%; ensure 1:1 quadriceps:hamstring exercise ratio
E	Limb Symmetry Pie Charts	Strength relative to involved limb	Goal: <10% asymmetry (either direction- deficit OR stronger on involved limb)	If <80%, continue NMES in addition to strength training If <90%, continue unilateral > bilateral strength training emphasis

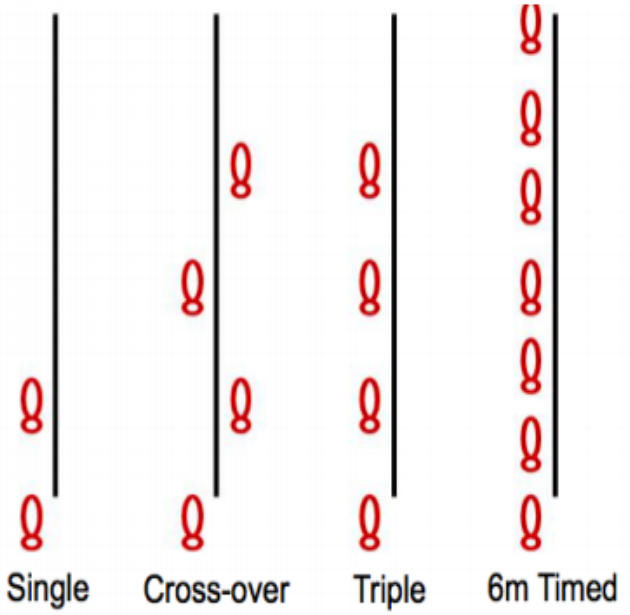
Appendix D: Isokinetic Testing and Appropriate Alternatives

Sinacore, J. A., Evans, A. M., Lynch, B. N., Joreitz, R. E., Irrgang, J. J., & Lynch, A. D. (2017). Diagnostic accuracy of handheld dynamometry and 1-repetition-maximum tests for identifying meaningful quadriceps strength asymmetries. *Journal of orthopaedic & sports physical therapy*, *47*(2), 97-107.

Isokinetic Dynamometry		• Considered the "gold standard" • 60°/sec for strength and power assessment • 300°/second for speed and endurance assessment
Hand Held Dynamometry with Static Fixation at 90°		• Appropriate alternative • Results may overestimate quadriceps strength symmetry: be cautious with data interpretation
SL 1RM Knee Extension Machine: 90°- 45°		• Appropriate alternative • Recommended to decrease stress on PF joint and limit strain on reconstructed ACL for up to 6 months • Results may overestimate quadriceps strength symmetry: be cautious with data interpretation
SL 1RM Leg Press		• Fair alternative • Results in significant overestimation of quadriceps strength symmetry due to compensation from other LE muscle groups
SL 1RM Knee Extension Machine: 90°- 0°		• Fair alternative • May be uncomfortable and/or inappropriate due to PF stress

Appendix E: Single Leg Hop Series

1) **Single hop for distance:** Have the subject line their heel up with the zero mark of the tape measure, wearing athletic shoes. The subject then hops as far as he/she can, landing on the same push off leg, for at least 3 seconds. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.
2) **Cross-over hop for distance:** The subject lines their heel up with the zero mark of the tape measure and hops 3 times on one foot, crossing fully over the center line each time. Each subject should hop as far forward as he/she can on each hop, but only the total distance hopped is recorded. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.
3) **Triple hop for distance:** The subject lines their heel up with the zero mark of the tape measure and hops 3 times on one foot. Each subject should hop as far forward as he/she can on each hop, but only the total distance hopped is recorded. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.
4) **Timed 6-meter hop:** The subject lines their heel up at the zero mark of the tape measure and hops, on cue with the tester, as fast as they can the length of the 6-meter tape. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb time/Uninvolved limb time X 100%.



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