QUADRICEPS TENDON/PATELLAR TENDON REPAIR CLINICAL PRACTICE GUIDELINE

Disclaimer

The following rehabilitation guidelines are specific to patients who have undergone a quadriceps tendon or patellar tendon repair surgical procedure. Please refer to the Ohio State Sports Medicine website for rehabilitation guidelines specific to other procedures and conditions, as appropriate.

Progression is criterion-based and dependent on soft tissue healing, patient demographics, and clinical evaluation. The time frames identified for each phase of rehabilitation are approximate times for the average patient and are not recommended as guidelines for progression for the individual patient. It is recommended that progression is based upon the achievement of functional criteria demonstrating readiness for progression, noted at the end of each phase.

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.

Background

The rehabilitation recommendations below are based upon the guidance of content experts, evidence-based practice, and literature review of best-practice guidelines. Progression through each phase is based on the patient demonstrating readiness by achieving functional criteria rather than the time elapsed from surgery. The time frames identified after each phase are approximate times for the average patient, NOT strict criteria for progression.

Summary of Recommendations

Always refer to the operative note for specific post-operative precautions indicated by the surgical team

Precautions	1. ROM – refer to operative note for guidelines a. No flexion > 90deg x 6 wks b. Goal: full flexion by post-op week 10 2. No loaded closed kinetic chain quad strengthening x 6 WEEKS to protect repair site 3. Open kinetic chain knee progression a. Multi-angle isometrics @ 4 WEEKS b. LAQ @ 6 WEEKS – add weight as able c. Knee extension machine @ 8 WEEKS (partial → full) 4. Weight Bearing a. FWBing with brace locked in extension x 6 WEEKS b. Typically WBing with TROM open x 1-2 weeks prior to discharge **c. *Please refer to the "post-op plan" section of the operative note for clarification***
Risk Factors	• Quad tendon repair requires extensive rehabilitation and can often exhaust insurance approved PT visits. Consider decreasing frequency during middle phase rehab • Long term quadriceps strength deficits are common ≥ 1 year post-operatively • Systemic comorbidities (Diabetes Mellitus, Rheumatoid Arthritis) are common in this patient population, important to consider PMH
Outcome Tools	Collect the LEFS at each visit *You may choose to include IKDC, KOOS, ACL-RSI, Tegner or other questionnaires specific to your patient's needs*.
Functional Testing	• Isometric Testing: 4 months + • Isokinetic Testing: 6 months + • Hop testing battery (Once 80% LSI achieved on isokinetic testing)
Criteria to Discharge Knee Brace	Discharge no earlier than 6 WEEKS post-op * Pending pt progress, unlock TROM during ambulation for 1-2 weeks prior to discharge 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 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 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 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 7. Physician Clearance
RTS Expectation	6-12 months

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
 	
Require immediate referral for re-evaluation
	• 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 post-op→*Refer to surgeon for re-evaluation*
	• Mechanical block or clunk→*Refer to surgeon for re-evaluation*
	• Reported episode of instability→*Refer to surgeon for re-evaluation*

Yellow Flags *Require modifications to plan of care*	• Persistent reactive effusion or pain following therapy or ADLs ○ *Decrease intensity of rehab interventions, continue effusion management, educate patient regarding activity modifications until symptoms resolve*

Protection Phase (Post-tendon repair – 6 weeks)

Appointments	• Goal: restore ROM, minimize effusion and pain. • Post-operative evaluation should be performed 5-7 days following surgery. • Follow-up appointments 1-2x per week, depending on ROM progression; be cautious of insurance limitations

Precautions	1. No loaded closed kinetic chain quad strengthening x 6 WEEKS to protect repair site
	2. Open kinetic chain knee progression
	  a. Multi-angle isometrics @ 4 WEEKS
	  b. LAQ @ 6 WEEKS – add weight as able
	3. Weight Bearing
	  a. FWBing with brace locked in extension x 6 WEEKS
	  b. Typically WBing with TROM open x 1-2 weeks prior to discharge
	  c. *Please refer to the "post-op plan" section of the operative note for clarification*
	4. Post-operative ROM should begin 5-7 days post-op, emphasis on pain-free range
	5. **No forced flexion** x 8-10 weeks
	6. **No weight bearing CKC therapeutic exercise x 6 weeks**
	7. **Unloaded** Open Chain knee extension – may begin in this phase, emphasis on pain-free and consider protected range to begin

Pain and Effusion	≤2+ (using Modified Stroke Test - *Appendix C*) • Effusion management strategies: cryotherapy and compression (ie. Donut, ace wrap) and limited WB therapeutic exercise as appropriate
ROM	<u>Patellar Mobility:</u> Weeks 0-4: Initiate medial/lateral patellar mobilizations (Gr I-II); SLOW progression of superior/inferior mobilizations Week 4: progress to Gr III-IV patellar mobilizations per pt tolerance <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 > 90deg x 6 wks

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	**Weeks 0-4** • Extension ROM: bag hangs or prone hangs *(Appendix A)* • Flexion ROM: heel slides, wall slides, upright bike • Patellar mobilization: medial & lateral okay early, slowly progress to superior & inferior • Quad Isometrics; SLR 4-way • TKE: prone and standing • Prone hamstring curls • Weight shifting, SL balance, steamboats • Neuromuscular re-education using electrical stimulation (NMES) in long sitting **Weeks 4-6** • Initiate Multi-angle knee isometrics from 90-60º@ 4 weeks • Initiate open chain knee extension exercises ○ Initiate unloaded LAQ at 6 weeks (partial → full range) • 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) • Neuromuscular re-education using electrical stimulation (NMES) in 60º knee flexion *without biofeedback (Appendix B)*
Blood Flow Restriction Training *Appendix D*	• Blood Flow Restriction (BFR) training can be initiated as soon as sutures are removed • Ensure patient has no contraindications (Appendix D) and if patient has any listed precautions or are at risk for a DVT, clear with physician before initiating BFR • Use BFR twice weekly for up to 10 weeks; use for 2-3 exercises per session • Can be used with any exercise that is safe for patient to perform depending on time since surgery (ex. SLR 4-way, prone TKE). *BFR should never be performed during a plyometric exercise.* • Training Load: 20-40% 1 RM (Estimated, or use OMNI-RES, see Appendix D) • Limb Occlusion Pressure= 80% (see Appendix D if patient unable to tolerate) • 4 sets for each exercise with reps of 30-15-15-15 (75 total) with a 30 second rest break between sets, keeping cuff inflated the entire duration of each exercise. Deflate between exercises, or every 8 minutes.
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 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)** 1. ROM: ≥ 0-120 degrees 2. Strength: Quadriceps set with normal superior patellar translation, SLR x 10 seconds without extensor lag 3. Effusion: ≤ 2+ with Modified stroke test 4. Weight Bearing: Able to tolerate CKC therex program without increased pain and ≤ 2+ effusion

Early Loading Phase (6-10 weeks)

Appointments	• Goal: to improve LE loading symmetry, increase strength and normalize gait mechanics • Consider decreasing visit frequency to 1x/wk with strong emphasis on home program compliance (3-4 days per week outside of therapy).
Precautions	• Open Chain knee extension – continue slow and controlled progression; begin external loading
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 • Continue aggressive techniques to achieve/maintain full knee extension if necessary (i.e. weighted bag hang) as needed • 6 weeks: begin actively progressing flexion ROM > 90deg. Goal: full flexion by 10 weeks *(Refer to surgeon for re-evaluation if not achieved)*

Suggested Interventions and timelines	• Consider introducing resisted upright bike or elliptical for cardio
	• Progress CKC quadriceps strengthening (begin protected range, progress to full range – refer to op-note for restrictions)
	  ○ Leg Press (bilateral, unilateral)
	  ○ Step up/down
	  ○ DL/SL squat
	  ○ Heel Tap
	• Multi-angle knee isometrics from 90-0º
	• Isotonic LAQ at 6 weeks; knee extension machine at 8 weeks (partial → full)
	• Continue isolated hamstring interventions
	  ○ RDL
	  ○ Swiss ball hamstring curls – eccentrics and single leg
	  ○ Progress isotonic hamstring strengthening
	• Progress gluteal and lumbopelvic strength and stability
	• Progress single leg balance
	  • Compliant surface, external focus of attention/perturbations
	• Initiate biofeedback with NMES if appropriate
	• BFR (continue as in early phase, adding appropriate exercises)

Criteria to Discharge 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 to 60 degrees with good quality 4. 10 rep max on LP and similar effort bilaterally 1. 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 (10-16 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).
Pain and Effusion	Cryotherapy/compression as needed for reactive effusion. Patellar taping and/or Cho-Pat strap to reduce PF symptoms if present

Suggested Interventions and timelines	• Consider initiating higher level warm ups, including bike sprints or versa-climber
	• Progress isotonic open chain knee extensions
	• Progress isotonic closed chain quadriceps strengthening
	• Continue isolated hamstring interventions
	  ○ RDL on compliant surface
	  ○ Nordic hamstring curls
	• Progress gluteal and lumbopelvic strength and stability
	• Progress single leg balance
	• Continue NMES as appropriate
	• BFR (continue as in early phase, adding appropriate exercises)

Functional Testing	• Isometric Testing: 4 months +
Criteria to Progress to Return to Function Phase	1. ROM: Maintain full, pain free AROM including PF mobility 2. Effusion: ≤ 1+ 3. Strength: Isometric quadriceps and hamstrings strength >/= 80% 4. Weight Bearing: Able to tolerate therapeutic exercise program, including jogging progression, without increased pain or >1+ effusion 5. Neuromuscular Control: Demonstrates proper lower extremity mechanics with all therapeutic exercises (bilaterally) 6. Outcome Tools: ≥ 7/10 on #10 IKDC Questionnaire

Return to Function Phase (4-6 months)

Appointments	• Goal: to return to prior level of function with daily activity.
	  • Consider decreasing visit frequency to 1x/wk with strong emphasis on home program compliance (3-4 days per week outside of therapy).
	  • 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).

Pain and Effusion	Cryotherapy/compression as needed for reactive effusion. Patellar taping and/or Cho-Pat strap to reduce PF symptoms if present
Suggested Interventions and timelines	• Progress isotonic open chain knee extensions • Progress isotonic closed chain quadriceps strengthening • Continue isolated hamstring interventions • Progress gluteal and lumbopelvic strength and stability • Progress single leg balance • Initiate PWB DL plyometrics on shuttle • Continue NMES
Functional Testing *Appendix E-F*	• Isometric Testing: 4 months + • Isokinetic Testing: 6 months +
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 3. Effusion: 1+ or less 4. Weight Bearing: normalized gait and jogging mechanics • Neuromuscular Control: Pain-free hopping in place

Return to Sport (> 6 months)

Appointments	Increased frequency from previous stage to 1-2x per week when appropriate to initiate plyometric training and return to running program.
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 pain-free 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
Functional Testing *Appendix E - G*	• Isokinetic Testing: 6 months + • Hop testing battery (Once 80% LSI achieved on isokinetic testing)
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

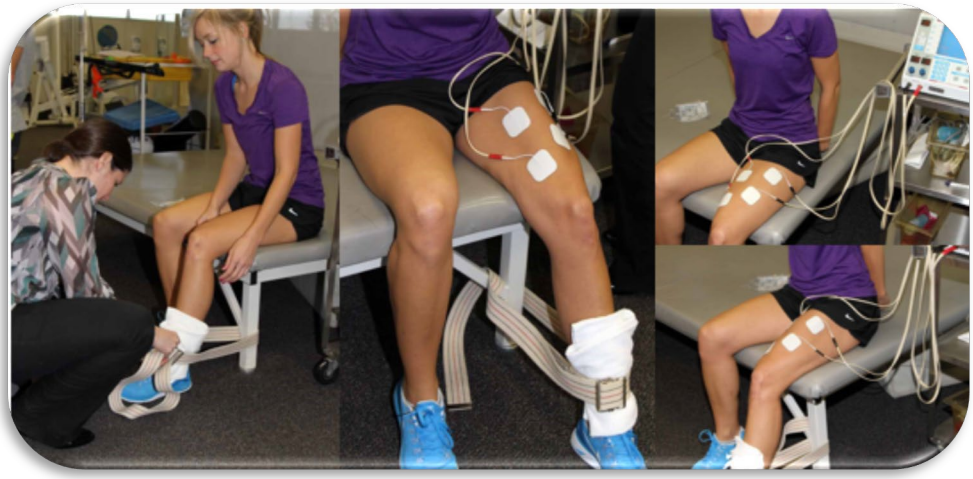
Emphasis on low load, long duration stretching

- *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



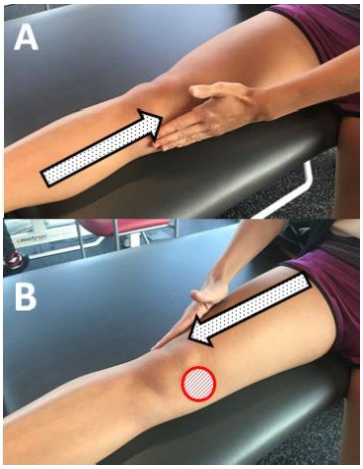
Appendix C: Stoke Test / Swelling Assessment

The Stroke Test

The stroke test is a great way to assess your swelling independently. The results of this assessment will help you decide what exercises are appropriate.

A. Using one hand, gently sweep the inside portion of your knee 2-3 times (pushing toward the hip joint).

B. On the outside portion of the knee, immediately sweep downward (toward the ankle). Watch the inside portion of the knee *(indicated by hashed circle in photo)* for a wave of fluid to appear during the downstroke.



Grading System

(Table adapted from Sturgill L et al, Journal of Orthopaedic & Sports Physical Therapy, 2009)

Test Result	Grade
No wave produced on downstroke	Zero
Small wave on inside aspect of knee with downstroke	Trace
Large bulge on inside aspect of knee with downstroke	1+
Swelling spontaneously returns to inside aspect of knee after upstroke (no downstroke necessary)	2+
So much fluid that it is not possible to move the swelling out of the inside aspect of the knee	3+

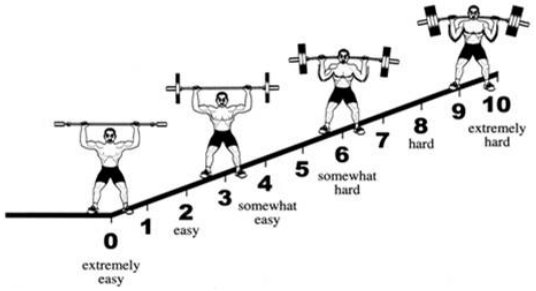
Indications for Activity

3+ or 2+	1+	Trace or Zero
Red Light	**Yellow Light**	**Green Light**
• No running, jumping or cutting or heavy lifting until swelling decreases to 1+ or less • Do not progress program until you speak with your therapist • Utilize swelling management strategies (ice, compression, elevation, NSAIDs)	• Proceed with caution • You may participate in running, jumping and normal lifting routine. • Check effusion before and after workouts • Utilize swelling management strategies (ice, compression, elevation, NSAIDs)	• May participate in running, jumping and normal lifting routine without restriction • Continue to monitor swelling after activity

Appendix D: Blood Flow Restriction Training

Precautions (must get permission from MD)	Contraindications
▪ Patients with poor circulatory systems (Indicators: shining or scaly skin, brittle dry nails, extremity hair loss, increased capillary filling time, and presence of varicose veins) ▪ Patients who are obese or with limb tissue that is loose ▪ Arterial claudification ▪ Abnormal clotting times ▪ Diabetes ▪ Sickle cell trait ▪ Tumor ▪ General infection ▪ Hypertension ▪ Cardiopulmonary conditions ▪ Renal compromise ▪ Clinically significant acid-base imbalance ▪ Atherosclerotic vessels ▪ Taking anti-hypertensive medications	▪ Venous thromboembolism ▪ Impaired circulation or peripheral vascular compromise ▪ Previous revascularization of the extremity ▪ Extremities with dialysis access ▪ Acidosis ▪ Sickle cell anemia ▪ Extremity infection ▪ Tumor distal to the tourniquet ▪ Medications/supplements known to ↑ clotting risk ▪ Open fracture ▪ Increased intracranial pressure ▪ Open soft tissue injuries ▪ Post-traumatic hand reconstructions ▪ Severe crushing injuries ▪ Severe hypertension ▪ Elbow surgery with excessive swelling ▪ Skin grafts in which all bleeding points distinguished ▪ Secondary or delayed procedures after immobilization ▪ Vascular grafting lymphectomies ▪ Cancer

Training Intensity: 20-40% 1RM or use the Omnibus Resistance Exercise Scale (below). Patient chooses weight/resistance that corresponds to 2-3



Exercise Prescription:

- If Patient achieves:
  - 75 repetitions: continue with training, re-assess intensity within 1-3 sessions and change as strength improves
  - 60-74 repetitions: continue with training, but extend rest period between sets 3 and 4 to 45 seconds until 75 repetitions is completed
  - 45-59 repetitions: continue with training, but extend rest period between all sets to 45-60 seconds
  - <44 repetitions: reduce load by approximately 10% until repetitions are achieved
- If patient is forced to stop before 75 repetitions due to undue pain, soreness, or general uncomfortable feeling underneath the cuff→ reduce tourniquet pressure by 10mmHg at each training session until cuff tolerance is achieved. Ramp cuff pressure back up by 10 mmHg to target limb occlusion pressure if patient can tolerate.

Appendix E: 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 F: 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

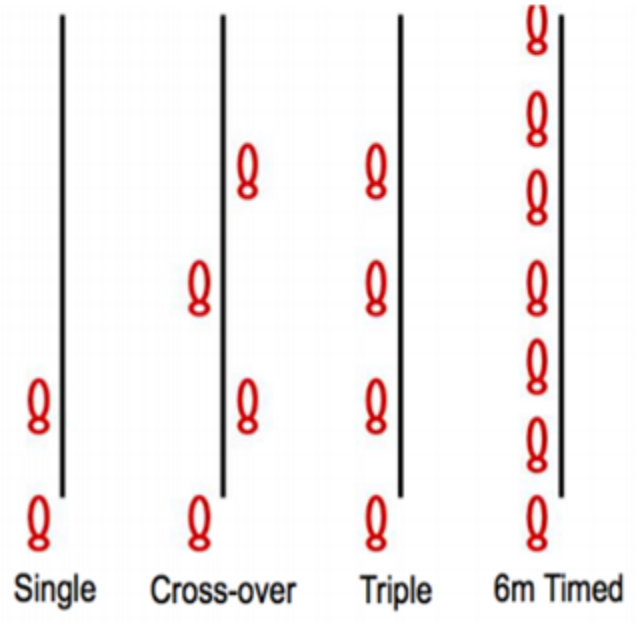
Appendix G: Single Leg Hop Series

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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References:

Boudissa M, Roudet A, Rubens-Duval B, Chaussard D. Acute quadriceps tendon ruptures: A series of 50 knees with an average follow-up of more than 6 years. Orthop Traumatol Surg Res 2014;100:217-220.

Ciriello V, Gudipati S, Tosoundis T, Soucacos PN, Giannoudis P. Clinical outcomes after repair of quadriceps tendon rupture: A systematic review. Injury Int J Care Injured 2012;43:1931-1938.

De Baere T, Geulette B, Manche E, Barras L. Functional results after surgical repair of quadriceps tendon rupture. Acta Orthopaedica Belgica 2002;68:146–9.

Konrath GA, Chen D, Lock T, Goitz HT, Watson JT, Moed BR, et al. Outcomes following repair of quadriceps tendon ruptures. Journal of Orthopaedic Trauma 1998;12:273–9.

Langenhan R, Baumann M, Ricart P, Hak D, Probst A, Badke A, et al. Postoperative functional rehabilitation after repair of quadriceps tendon ruptures: a comparison of two different protocols. Knee Surg Sports Traumatol Arthrosc 2012;20:2275–8.

O'Shea K, Kenny P, Donovan J, Condon F, McElwain JP. Outcomes following quadriceps tendon ruptures. Injury 2002;33:257–60.

Ramseier LE, Werner CM, Heinzelmann M. Quadriceps and patellar tendon rupture. Injury 2006;37:516–9.

Rougraff BT, Reeck CC, Essenmacher J. Complete quadriceps tendon ruptures. Orthopedics 1996;19:509–14.

Saragaglia D, Pison A, Rubens-Duval B. Acute and old ruptures of the extensor apparatus of the knee in adults (excluding knee replacement). Orthop Traumatol Surg Res 2013;99(Suppl 1):S67–76.

Vidil A, Ouaknine M, Anract P, Tomeno B. Trauma-induced tears of the quadriceps tendon: 47 cases. Rev Chir Orthop 2004;90:40–8.

Waligora AC, Johanson NA, Hirsch BE. Clinical anatomy of the quadriceps femoris and extensor apparatus of the knee. Clin Orthop Relat Res 2009;467:3297–306.

Wenzl ME, Kirchner R, Seide K, Strametz S, Jurgens C. Quadriceps tendon ruptures—is there a complete functional restitution? Injury 2004;35:922–6.

West JL, Keene JS, Kaplan LD. Early motion after quadriceps and patellar tendon repairs: outcomes with single-suture augmentation. Am J Sports Med 2008;36:316–23.