

HIGH TIBIAL/DISTAL FEMUR OSTEOTOMY CLINICAL PRACTICE GUIDELINE

Disclaimer

The following rehabilitation guidelines are specific to patients who have undergone a high tibial osteotomy (HTO) surgical procedure. Please refer to the Ohio States 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 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.

Background

High Tibial Osteotomy (HTO) is an elective surgical procedure designed to correct knee malalignment with associated pain and stiffness. This procedure is a widely accepted treatment option for patients younger than 60 years old with symptomatic medial compartment knee arthrosis associated with varus osseous deformity. However it is also indicated in varus angulated knees in younger patients, or patients with concomitant articular cartilage procedures (osteochondral grafts, autologous chondrocyte implantation), meniscus transplantation, or ligamentous instability.¹⁻³ The goal of the osteotomy is to relieve medial compartment knee pain, slow the degenerative process, and delay joint replacement by unloading the medial compartment and reducing the stress on the medial compartment or the ligamentous structures of the knee.²⁻⁵

Multiple HTO techniques can be performed, dependent on patient presentation and surgeon preference. The most common technique is the medial opening wedge HTO, as it allows for precise correction (correcting alignment in both coronal and sagittal planes) and avoids the need for a fibular osteotomy.⁷⁻⁹ Anterior closing wedge osteotomies also can be performed if greater correction is needed.⁹ Weight bearing status may change depending on type of procedure and size of correction performed.

The rehabilitation recommendations below are based upon the guidance of content experts, surgeons, and evidence-based practice. Progression through each phase, after precautions have been lifted, is based on the patient demonstrating readiness by achieving functional criteria.



Summary of Recommendations

Precautions	<ul style="list-style-type: none"> With concomitant procedures, range of motion or weight bearing precautions may be adjusted. These include: <ul style="list-style-type: none"> Meniscal Repair: no forced flexion ROM beyond 90 degrees x4 weeks Autologous Chondrocyte Implantation (MACI, NeoCart, NovoCart): full WB may be delayed to 8-12 weeks. ROM progression may be slowed Please refer to the “post-op plan” section of the operative note for clarification
Risk Factors	The patient should be monitored for signs and symptoms of DVT (see Red/Yellow Flag section)
Weight Bearing	<p>Medial Opening Wedge HTO:</p> <ul style="list-style-type: none"> Weeks 0-2: TTWBIing Weeks 2-4: 25% WB Weeks 4-6: 50% WB Weeks 6-8: WBAT with crutches <p>Anterior closing wedge HTO:</p> <ul style="list-style-type: none"> Weeks 0-2: TTWBIing Weeks 2+: progress to full WBing <p>WB progression may be delayed with a larger correction (>10 degrees or >10 mm correction)</p> <p>Please refer to the “post-op plan” section of the operative note or contact the surgeon for clarification</p>
Range of Motion	<ul style="list-style-type: none"> Week 0-2: 0-110° Week 2+: progress to full flexion ROM <p>*symmetrical knee extension should be achieved by week 4. If not achieved by week 4, contact surgeon.</p>
Outcome Tools	<p>Collect the LEFS at each visit</p> <p><i>You may choose to include IKDC, KOOS, ACL-RSI, Tegner or other questionnaires specific to your patient’s needs</i></p>
Strength Considerations	HTO results in slow recovery of quadriceps muscle strength. Significant emphasis on quadriceps strengthening is crucial for recovering muscle power. Muscle recovery can take >6 months after HTO, particularly with varus angles >5 degrees
Functional Testing	<ul style="list-style-type: none"> Isometric testing at 2-3 months <ul style="list-style-type: none"> Delay to 4-5 months with concomitant ACI Isokinetic testing at 6, 9, 12 months and discharge Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing) <ul style="list-style-type: none"> SL hop for distance Triple hop Cross over hop Timed 6m hop <i>*Functional strength testing and hop testing should be reserved for patients returning to high level activity*</i>
Criteria to Discharge Assistive Device	<ul style="list-style-type: none"> ROM: Full active knee extension; no pain on passive overpressure Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag Effusion: 1+ or less is preferred (2+ acceptable if all other criteria are met) Weight Bearing: Demonstrates pain-free ambulation without visible gait deviation



Criteria to D/C NMES	<ul style="list-style-type: none"> • <20% quad deficit on isometric testing • If Biodex not available: <ul style="list-style-type: none"> ○ 10 SLR without quad lag ○ Normal gait ○ 10 heel taps to 60° knee flexion with good quality ○ 10 rep max on leg press and similar effort bilaterally ○ Inability to break quad MMT (5/5)
Criteria to Initiate Running and Jumping	<ul style="list-style-type: none"> • ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb • Strength: Isokinetic testing 80% or greater for hamstring and quad at 60°/sec and 300°/sec • Effusion: 1+ or less • Weight Bearing: normalized gait and jogging mechanics • Neuromuscular Control: Pain-free hopping in place
Criteria to Return to Sports Participation	<ul style="list-style-type: none"> • ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb • Strength: Isokinetic testing 90% or greater for hamstring and quad at 60°/sec and 300°/sec • Effusion: No reactive effusion ≥ 1+ with sport-specific activity • Weight Bearing: normalized gait and jogging mechanics • Neuromuscular control: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements • Functional Hop Testing: LSI 90% or greater for all tests • Physician Clearance
Return to Sport Expectation	6-12 months

RED/YELLOW FLAGS

<p>Red Flags</p> <p><i>Require immediate referral for re-evaluation</i></p>	<ul style="list-style-type: none"> • Signs of DVT → <i>Refer directly to ED</i> <ul style="list-style-type: none"> ○ 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 → <i>Refer to surgeon for re-evaluation</i> • Mechanical block or clunk → <i>Refer to surgeon for re-evaluation</i> • Reported episodes of instability → <i>Refer to surgeon for re-evaluation</i>
<p>Yellow Flags</p> <p><i>Require modifications to plan of care</i></p>	<ul style="list-style-type: none"> • Persistent reactive effusion or pain following therapy or ADLs <ul style="list-style-type: none"> ○ <i>Decrease intensity of rehab interventions, continue effusion management, educate patient regarding activity modifications until symptoms resolve</i>



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Phase I: Protection (Post-Operative—4 weeks)

Goals	Restore ROM, minimize effusion and pain while adhering to all post-operative precautions
Pain and Effusion	Effusion management strategies: cryotherapy and compression as appropriate
ROM	<ul style="list-style-type: none"> • Week 0-2: 0-110 deg • Week 2+: progress to full flexion ROM <i>*avoid active hamstring activity for first 2 weeks</i> • Recommend ROM exercise as soon as possible after surgery to decrease articular swelling, scar tissue formation and joint stiffness • Strong emphasis on patellar mobilizations (all directions) to regain full knee ROM • Contact MD by 4 weeks post op if ROM concerns
Weight Bearing	<p>Medial Opening Wedge HTO:</p> <ul style="list-style-type: none"> • Weeks 0-2: TTWBing • Weeks 2-4: 25% WB <p>Anterior closing wedge HTO:</p> <ul style="list-style-type: none"> • Weeks 0-2: TTWBing • Weeks 2+: progress to full WBing <p>**WB progression may be delayed with a larger correction (>10 degrees or >10 mm correction)** <i>Please refer to the “post-op plan” section of the operative note or contact the surgeon for clarification</i></p>
Suggested Interventions	<ul style="list-style-type: none"> • Ankle pumps • Quadriceps, hamstring and gluteal isometrics • Diaphragmatic breathing • Effusion management strategies, including RICE • Prone TKE • SLR-4 way • Patellar mobilization in all directions • Gait training • Extension ROM: Seated towel stretch, prone hang (Appendix A), bag hang • Flexion ROM: heel slides, wall slides <ul style="list-style-type: none"> ○ Can progress to supine knee flexion with legs on ball, prone knee flexion after 2 weeks • Recumbent cycling- for ROM only (week 2) <ul style="list-style-type: none"> ○ ½ circles → full circles- lower seat as tolerated • SAQ • LAQ (through protected ROM (90-45 degrees) • Clamshell • Maintain hamstring and calf flexibility • NMES in long sitting
Blood Flow Restriction Training <i>Appendix D</i>	<ul style="list-style-type: none"> • Blood Flow Restriction (BFR) training can be initiated at the 6 week mark for this patient population. • Ensure patient has no contraindications (Appendix F) 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 2-5 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).



Blood Flow Restriction Training <i>Appendix D</i>	<ul style="list-style-type: none"> • <i>BFR should never be performed during a plyometric exercise.</i> • Training Load: 20-40% 1 RM (Estimated, or use OMNI-RES, see Appendix F) • Limb Occlusion Pressure= 80% (see Appendix F 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 <i>Long Sitting</i>	<ul style="list-style-type: none"> • NMES pads are placed on the proximal and distal quadriceps • Patient: Seated in long sitting (knees extended). Progress to seated with the knee in at least 60° 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 quadriceps contraction OR maximal tolerable amperage without knee joint pain • 20 seconds on/ 50 seconds off x 15 min
Criteria to Progress to Early Loading Phase	<ul style="list-style-type: none"> • Pain-free knee flexion of >120 degrees • Pain-free and full passive knee extension • Proficient heel-to-toe gait with 25% BW • Reduced and well-controlled post-operative pain and edema • Ability to perform a strong isometric quadriceps contraction (full tetany and superior patellar glide) • Proficiency with home-exercise program



Phase II: Early Loading (4-8 weeks)

Goals	Emphasis is placed on normalizing ROM and improving quadriceps, gluteal and core strength
Pain and Effusion	Cryotherapy/compression as needed for reactive effusion
ROM	Full and pain-free ROM
Weight Bearing	<p>Medial Opening Wedge HTO:</p> <ul style="list-style-type: none"> • Weeks 2-4: 25% WB • Weeks 4-6: 50% WB • Weeks 6-8: WBAT with crutches <p>Anterior closing wedge HTO:</p> <ul style="list-style-type: none"> • WBAT post-op day
Suggested Interventions	<ul style="list-style-type: none"> • Continue Phase 1 and 2 interventions • Continue effusion management strategies • BFR (continue as in early phase, adding appropriate exercises) • SLR-Flexion progressions <ul style="list-style-type: none"> ○ Semi-reclined or seated ○ Add ER ○ Perform with eyes closed (cortical training) ○ Speed ○ Isometric holds at end-range • Standing TKE • Multi-Angle knee isometrics from 90-60 degrees • Bridges • Trunk stability interventions <ul style="list-style-type: none"> ○ TrA progression ○ Prone/side planks (modified-> full plank) • Partial BW Shuttle Press (DL→SL) • Closed Chain exercises: mini-squats, wall sits, heel raises, TKE • OKC Knee Extension (90-30 deg ROM) (week 7+) • OKC Hamstring strengthening (week 6+) • Progress NMES to seated with tibia fixed at 60° of knee flexion
NMES Parameters (with tibia fixed at 60° of knee flexion) <i>Appendix B</i>	<ul style="list-style-type: none"> • NMES pads are placed on the proximal and distal quadriceps • Patient: Seated with the knee in at least 60° 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	<ul style="list-style-type: none"> • ROM: Full active knee extension; no pain on passive overpressure • Strength: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag • Effusion: 1+ or less is preferred (2+ acceptable if all other criteria are met) • Weight Bearing: Demonstrates pain-free ambulation without visible gait deviation
Criteria to Progress to Strengthening and Return to Function Phase	<ul style="list-style-type: none"> • ROM: full and painless AROM and normalized PF mobility • Effusion: <1+ • Strength: Quadriceps set with normal superior patellar translation, SLR x10" without extensor lag • WB: able to tolerate CKC therex program without increased pain or effusion

Phase III: Strengthening/Return to Function (8-16 Weeks)

Goals	<ul style="list-style-type: none"> • Wean off crutches to normalized gait • Progress functional balance/NM control • Progress LE strengthening • Progress core stability
Pain and Effusion	Monitor reactive effusion as progressive loading is performed
ROM	Full ROM with no complaints of pain with end-range overpressure
Weight Bearing	FWB with normalized gait pattern
Suggested Interventions	<p>*Caution should be exercised when engaging in CKC knee flexion of approximately 90 degrees and stepping downstairs in early postoperative period</p> <ul style="list-style-type: none"> • Continue Phase 2 and 3 interventions as appropriate • BFR (continue as in early phase, adding appropriate exercises) • Multi-angle isometrics • Balance and proprioception interventions • BOSU Squats, lunges • Mini squats: 0-45 degrees (week 8-10) • Heel Taps: 2-4" (weeks 10-12) • Step Ups: 6-8" (weeks 10-12) • Resisted OKC quadriceps strengthening through full ROM (week 12-14) • Lunges • SL sit to stand, through protected ROM • Core strengthening • Conditioning: <ul style="list-style-type: none"> ○ Elliptical ○ Swimming ○ Outdoor cycling if desired (12+ weeks) ○ Rowing ergometry as tolerated • Continue NMES until 80% symmetry is obtained • Continue effusion management as needed
Strength Testing	<ul style="list-style-type: none"> • Isometric testing at 2-3 months <ul style="list-style-type: none"> ○ Delay to 4-5 months with concomitant ACI



Criteria to Discharge NMES	<ul style="list-style-type: none"> • <20% quad deficit on isometric testing OR if Biodex machine is not available: <ul style="list-style-type: none"> • 10 SLR without quad lag • Normal gait • 10 heel taps to 60 deg knee flexion with good quality • 10 rep max on Leg Press and similar effort bilaterally • Inability to break quad MMT
Criteria to Progress to Return to Activity Phase	<ul style="list-style-type: none"> • ROM: maintain full, pain free AROM • Effusion: <1+ • Strength: Isometric or isokinetic quadriceps and hamstrings strength \geq 80% • Weight Bearing: able to tolerate therapeutic exercise program, including jogging progression, without increased pain or >1+ effusion • NM control: demonstrates proper lower extremity mechanics with all therapeutic exercises



Phase IV: Return to Activity (4 – 6 months)

Goals	Progress OKC interventions. Patients should continue skilled physical therapy to progress functional strengthening. Strength testing is performed to determine readiness to initiate light plyometrics and walk-jog progression.
Pain and Effusion	Monitor reactive effusion as progressive loading performed
ROM	Full ROM with no complaints of pain with end-range overpressure
Weight Bearing	FWB with normalized gait pattern
Strength Testing	<ul style="list-style-type: none"> • Isometric testing at 2-3 months <ul style="list-style-type: none"> ○ Delay to 4-5 months with concomitant ACI • Isokinetic testing at 6, 9, 12 months and discharge • Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing) <ul style="list-style-type: none"> ○ SL hop for distance ○ Triple hop ○ Cross over hop ○ Timed 6m hop <p><i>*Functional strength testing and hop testing should be reserved for patients returning to high level activity*</i></p>
Suggested Interventions	<p>Performance of the quadriceps, hamstrings and trunk dynamic stability</p> <ul style="list-style-type: none"> • 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 <p>Once strength criteria have been met, perform the following progression:</p> <ul style="list-style-type: none"> • PBW jumping on the shuttle (DL → SL) • Full body weight jumping progression • Walk-jog program
Criteria to Initiate Running and Jumping (4+ months)	<ul style="list-style-type: none"> • ROM: full, pain-free knee ROM, symmetrical with the uninvolved limb • Strength: Isokinetic testing 80% or greater for hamstring and quad at 60°/sec and 300°/sec • Effusion: 1+ or less • Weight Bearing: normalized gait and jogging mechanics • Neuromuscular Control: Pain-free hopping in place
Criteria to Progress to Return to Sport Phase	<ul style="list-style-type: none"> • Quadriceps and hamstring symmetry of 80% or greater • Ability to tolerate walking distances of 3 miles or greater without reactive pain or effusion • Ability to effectively negotiate uneven ground, including soft sand, without reactive pain or effusion • Ability to return to pre-operative low-impact recreational activities, including cycling, elliptical and weight training



Phase V: Return to Sport (6 months - RTS)

Goals	The patient is able to resume all normal functionality and will continue to progress towards return to sport
Pain and Effusion	Monitor reactive effusion as progressive loading performed
ROM	Full ROM with no complaints of pain during end-range overpressure
Weight Bearing	FWB with normalized gait pattern
Strength Testing	<ul style="list-style-type: none"> • Isokinetic testing at 6, 9, 12 months and discharge • Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing) <ul style="list-style-type: none"> ○ SL hop for distance ○ Triple hop ○ Cross over hop ○ Timed 6m hop <p><i>*Functional strength testing and hop testing should be reserved for patients returning to high level activity*</i></p>
Suggested Interventions	<ul style="list-style-type: none"> • Continue progressive strength training per previous phases <p>Agility</p> <ul style="list-style-type: none"> • 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. • Side shuffling, Carioca, Figure 8, Zig-zags, Resisted jogging (Sports Cord) in straight planes, backpedaling <p>Plyometrics</p> <ul style="list-style-type: none"> • 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 <p>Sport and position specific training</p>
Criteria for Return to Sport	<ul style="list-style-type: none"> • ROM: full, pain free knee ROM, symmetrical with the uninvolved limb • Strength: Isokinetic testing 90% or greater for hamstring and quad at 60°/sec and 300°/sec • Effusion: No reactive effusion ≥ 1+ with sport-specific activity • Weight Bearing: normalized gait and jogging mechanics • Neuromuscular Control: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements • Functional Hop Testing: LSI 90% or greater for all tests • Physician Clearance



Appendix A: Bag Hang

Emphasis on low load, long duration stretching

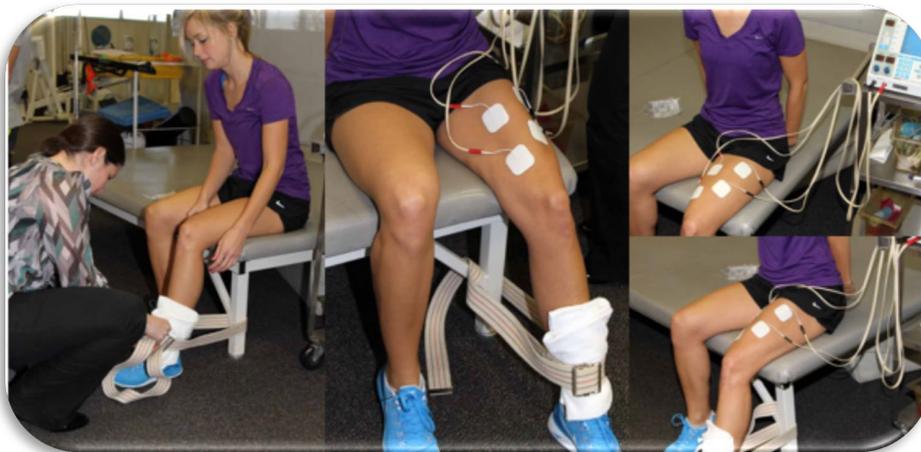
- Goal: 60 minutes of bag hang time total per day.
- Ideally: 4x15 minutes (or greater) per day



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 60° 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

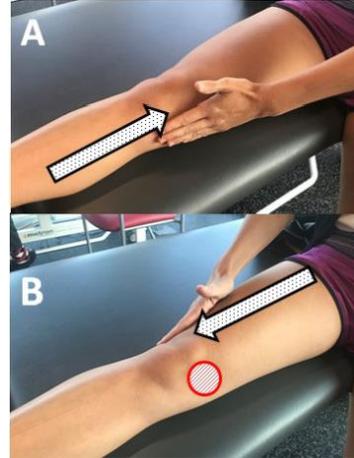


Appendix C: Stoke Test / Swelling Assessment

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

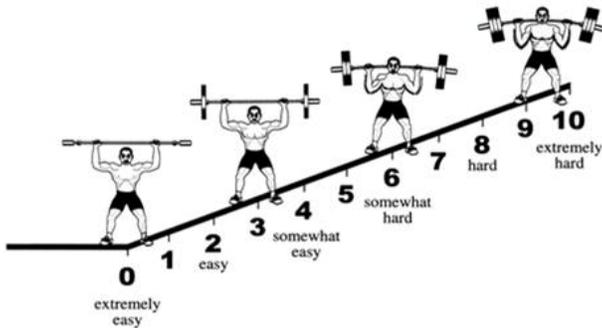
3+ or 2+	1+	Trace or Zero
Red Light 	Yellow Light 	Green Light 
<ul style="list-style-type: none"> No running, jumping or cutting or heavy lifting until swelling decreases to 1+ or less Do not progress program until you speak with your therapist Utilize swelling management strategies (ice, compression, elevation, NSAIDs) 	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> 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
<ul style="list-style-type: none"> ▪ 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 claudication ▪ Abnormal clotting times ▪ Diabetes ▪ Sick cell trait ▪ Tumor ▪ General infection ▪ Hypertension ▪ Cardiopulmonary conditions ▪ Renal compromise ▪ Clinically significant acid-base imbalance ▪ Atherosclerotic vessels ▪ Taking anti-hypertensive medications 	<ul style="list-style-type: none"> ▪ Venous thromboembolism ▪ Impaired circulation or peripheral vascular compromise ▪ Previous revascularization of the extremity ▪ Extremities with dialysis access ▪ Acidosis ▪ Sick 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



		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

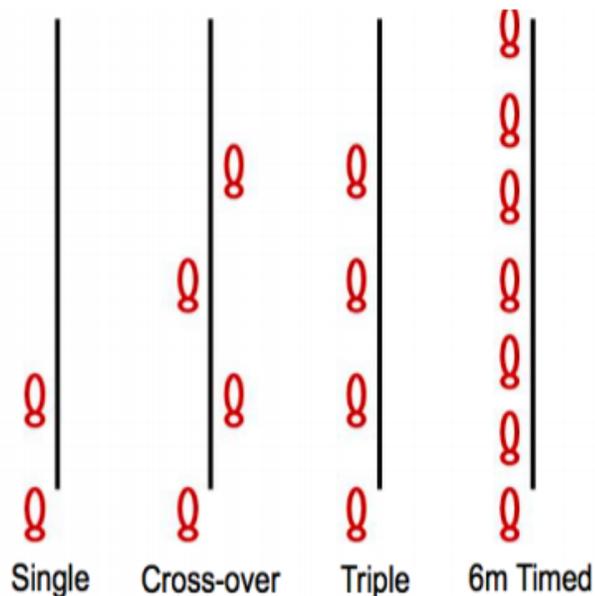
Sinacore, J. A., Evans, A. M., Lynch, B. N., Joreitz, R. E., Irrgang, J. J., & Lynch, A. D. (2017). Diagnostic accuracy of handheld dynamometry and 1-repetition-maximum tests for identifying meaningful quadriceps strength asymmetries. *Journal of orthopaedic & sports physical therapy*, 47(2), 97-107.

<p>Isokinetic Dynamometry</p>		<ul style="list-style-type: none"> • Considered the “gold standard” • 60°/sec for strength and power assessment • 300°/second for speed and endurance assessment
<p>Hand Held Dynamometry with Static Fixation at 90°</p>		<ul style="list-style-type: none"> • Appropriate alternative • Results may overestimate quadriceps strength symmetry: be cautious with data interpretation
<p>SL 1RM Knee Extension Machine: 90° - 45°</p>		<ul style="list-style-type: none"> • 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
<p>SL 1RM Leg Press</p>		<ul style="list-style-type: none"> • Fair alternative • Results in significant overestimation of quadriceps strength symmetry due to compensation from other LE muscle groups
<p>SL 1RM Knee Extension Machine: 90° - 0°</p>		<ul style="list-style-type: none"> • 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: $\text{Involved limb distance} / \text{Uninvolved limb distance} \times 100\%$.
- 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: $\text{Involved limb distance} / \text{Uninvolved limb distance} \times 100\%$.
- 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: $\text{Involved limb distance} / \text{Uninvolved limb distance} \times 100\%$.
- 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: $\text{Involved limb time} / \text{Uninvolved limb time} \times 100\%$.



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