

# MEDIAL PATELLOFEMORAL LIGAMENT RECONSTRUCTION WITH FULKERSON PROCEDURE CLINICAL PRACTICE GUIDELINE

## Background

Lateral patellar dislocation is among the most frequently identified acute knee injuries in children<sup>1,2</sup>, with an annual incidence rate of 43 per 100,000 in the US population<sup>2</sup>. First-time patellar dislocations are most common in young, active patients and can severely affect quality of life by resulting in chronic pain, loss of function, and degenerative changes of the patellofemoral joint<sup>2,3</sup>. While conservative treatment is often utilized for primary dislocations, up to 50% of individuals will go on to experience a recurrent dislocation event<sup>4-7</sup>. Surgical intervention can be indicated for individuals who experience recurrent episodes of patellar instability<sup>8,9</sup>. As the MPFL is often injured during a lateral patellar dislocation and is considered the primary static restraint to lateral translation, it is often targeted for surgical reconstruction to restore patellar stability in this patient population<sup>8,9</sup>.

Varying surgical techniques exist for performing a MPFL reconstruction with multiple autograft choices available—including but not limited to hamstring tendon, adductor magnus tendon, vastus medialis obliquus, or quadriceps tendon<sup>8,9</sup>. Allograft tissue has also been utilized with some success<sup>8</sup>. The operative procedure will secure the graft to the patella and attach it to the medial femoral condyle, with the goal of maintaining the native anatomical alignment<sup>8-11</sup>.

The Fulkerson procedure is a type of osteotomy performed to further address patellofemoral pain and instability. This additional procedure reduces patellofemoral pain by anteriorizing the tibial tubercle – resulting in decreased joint contact forces, while simultaneously medializing the extensor mechanism for increased stability.<sup>12</sup> The addition of this procedure to the standard MPFL reconstruction may result in changes to the initial phases of the rehab protocol. **Please refer to the surgeon's operative note for individual specifics.**

**Guidelines will need to be modified to respect healing tissue pending graft choice, as appropriate.** New evidence suggests that adolescent athletes who are undergo a MPFL reconstruction may require prolonged rehabilitation (>8 months) to allow for safe return to sport.<sup>13</sup> As such, **adherence to timeline plus criteria for progression rather than timeframe only is strongly recommended.**

## Disclaimer

The following rehabilitation guidelines are specific to patients who have undergone a medial patellofemoral ligament (MPFL) reconstruction 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.



## Summary of Recommendations

<p><b>Precautions</b></p>	<ul style="list-style-type: none"> <li>• Typically, NWBing x 6 week in TROM immobilizer             <ul style="list-style-type: none"> <li>○ <b>However, this depends on the specific direction and type of osteotomy. ALWAYS refer to the operative note to confirm WBing status, or reach out to the surgical team for confirmation</b></li> </ul> </li> <li>• Protected electrical stimulation program (NMES)</li> <li>• Patellar mobilizations—passive superior/medial glide only for 6 weeks             <ul style="list-style-type: none"> <li>○ <b>NO lateral patellar glides</b></li> </ul> </li> <li>• Avoid isolated strengthening of graft musculature (hamstring, etc) until 8 weeks</li> <li>• No open kinetic chain (OKC) strengthening x 4 weeks</li> </ul>
<p><b>Corrective Interventions</b></p>	<ul style="list-style-type: none"> <li>• Manual therapy for patellar mobility and knee ROM</li> <li>• NMES for quadriceps activation</li> <li>• Vasopneumatic cryotherapy for pain and edema control</li> <li>• Core and LE progressive resistance strengthening</li> <li>• Neuromuscular training for LE strength and mechanics</li> <li>• Sport-specific activity training</li> </ul>
<p><b>Functional Testing</b></p>	<ul style="list-style-type: none"> <li>• Isometric testing at 10 weeks</li> <li>• Isokinetic testing at 12 weeks</li> <li>• Functional hop testing at <math>\geq</math> 12 weeks and once LSI of 80% or greater is achieved</li> </ul>
<p><b>Patient Reported Outcomes</b></p>	<p>Collect at least one of the following at initial evaluation, every 6 weeks and discharge. Be consisted with which outcome tool is collected.</p> <ul style="list-style-type: none"> <li>• Knee Injury and Osteoarthritis Outcome Score (KOOS)</li> <li>• International Knee Documentation Committee (IKDC)</li> </ul>
<p><b>Criteria to Discharge Assistive Device</b></p>	<ol style="list-style-type: none"> <li>1. <u>ROM</u>: Full active knee extension; no pain on passive overpressure</li> <li>2. <u>Strength</u>: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag</li> <li>3. <u>Effusion</u>: 1+ or less is preferred (2+ acceptable if all other criteria are met)</li> <li>4. <u>Weight Bearing</u>: Demonstrates pain-free ambulation without visible gait deviation</li> </ol>
<p><b>Criteria to Discharge NMES</b></p>	<ul style="list-style-type: none"> <li>• &lt;20% quad deficit on isometric testing</li> <li>• If Biodex not available:             <ul style="list-style-type: none"> <li>○ 10 SLR without quad lag</li> <li>○ Normal gait</li> <li>○ 10 heel taps to 60° knee flexion with good quality</li> <li>○ 10 rep max on leg press and similar effort bilaterally</li> <li>○ Inability to break quad MMT (5/5)</li> </ul> </li> </ul>
<p><b>Criteria to Initiate Running and Jumping</b></p>	<ol style="list-style-type: none"> <li>1. <u>ROM</u>: full, pain-free knee ROM, symmetrical with the uninvolved limb</li> <li>2. <u>Strength</u>: Isokinetic testing 80% or greater for hamstring and quad at 60°/sec and 300°/sec</li> <li>3. <u>Effusion</u>: 1+ or less</li> <li>4. <u>Weight Bearing</u>: normalized gait and jogging mechanics</li> <li>5. <u>Neuromuscular Control</u>: Pain-free hopping in place</li> </ol>
<p><b>Criteria to Return to Sports Participation</b></p>	<ol style="list-style-type: none"> <li>1. <u>ROM</u>: full, painfree knee ROM, symmetrical with the uninvolved limb</li> <li>2. <u>Strength</u>: Isokinetic testing 90% or greater for hamstring and quad at 60°/sec and 300°/sec</li> <li>3. <u>Effusion</u>: No reactive effusion <math>\geq</math> 1+ with sport-specific activity</li> <li>4. <u>Weight Bearing</u>: normalized gait and jogging mechanics</li> <li>5. <u>Neuromuscular control</u>: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements</li> <li>6. <u>Functional Hop Testing</u>: LSI 90% or greater for all tests</li> <li>7. <u>Physician Clearance</u>: return to sport expectation— 4.5-9 months</li> </ol>



## RED/YELLOW FLAGS

### 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*

## FULKERSON PROCEDURE: WB AND BRACE PROGRESSION

*Defer to operative note & surgeon to confirm WBing status and progression*

### Weeks 0-6

- Typically, NWBing x 6 week in TROM immobilizer
  - **However, this depends on the specific direction and type of osteotomy. ALWAYS refer to the operative note to confirm WBing status, or reach out to the surgical team for confirmation**

### Weeks 6-8

- Open knee brace to available range ~6 weeks
- Work to normalize gait mechanics
- Criteria to discharge brace:
  - Able to ambulate 500 ft or greater without obvious gait deviation or gait decompensation with fatigue/longer distances
  - No evidence of quad lag during 3x10 SLR



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## Phase IA: Protection (Post-Operative—2 weeks)

<b>Goals Phase IA</b>	<ul style="list-style-type: none"> <li>• Protect Repair</li> <li>• Reduce pain and inflammation</li> <li>• Achieve normal knee ROM</li> <li>• Prevent muscle atrophy—regain active quadriceps contraction</li> </ul>
<b>Gait</b>	<ul style="list-style-type: none"> <li>• NWBing in TROM immobilizer</li> </ul>
<b>ROM</b>	<ul style="list-style-type: none"> <li>• Begin passive, active-assisted, and active ROM as tolerated             <ul style="list-style-type: none"> <li>◦ ROM can be progressed as tolerated unless otherwise noted by surgeon                 <ul style="list-style-type: none"> <li>▪ No forced flexion beyond 90° with concomitant meniscal repair</li> </ul> </li> </ul> </li> <li>• Intervention suggestions:             <ul style="list-style-type: none"> <li>◦ Bag hangs (Appendix A)</li> <li>◦ Biking—begin with ½ revolutions and progress to full revolutions</li> <li>◦ Heel slides</li> <li>◦ Stretching—IT band; gastroc/soleus in seated</li> <li>◦ Patellar mobilizations—<b>NO</b> lateral mobilization (superior/inferior only)</li> </ul> </li> </ul>
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• Quad Sets—long-sitting, prone, standing</li> <li>• Glute Sets</li> <li>• SLR in flexion, abduction; <i>Avoid extensor lag</i></li> <li>• Neuromuscular electrical stimulation (NMES) to quadriceps at 60°-90° flexion if quad inhibition present (Appendix B)             <ul style="list-style-type: none"> <li>◦ Multi-angle knee extensor isometrics from 60°-90° are also appropriate for those patients who cannot tolerate high-intensity NMES</li> </ul> </li> </ul>
<b>Blood Flow Restriction Training</b> <i>Appendix D</i>	<ul style="list-style-type: none"> <li>• Blood Flow Restriction (BFR) training can be initiated as soon as sutures are removed</li> <li>• 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</li> <li>• Use BFR twice weekly for up to 10 weeks; use for 2-3 exercises per session</li> <li>• Can be used with any exercise that is safe for patient to perform depending on time since surgery (ex. SLR 4-way, prone TKE). <i>BFR should never be performed during a plyometric exercise.</i></li> <li>• Training Load: 20-40% 1 RM (Estimated, or use OMNI-RES, see Appendix D)</li> <li>• Limb Occlusion Pressure= 80% (see Appendix D if patient unable to tolerate)</li> <li>• 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.</li> </ul>
<b>Pain &amp; Effusion</b>	<ul style="list-style-type: none"> <li>• Ice/cryotherapy, compression, elevation to reduce post-operative effusion</li> </ul>
<b>Criteria to Discharge Assistive Device</b>	<ul style="list-style-type: none"> <li>• <u>ROM</u>: Full active knee extension; no pain on passive overpressure</li> <li>• <u>Strength</u>: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag</li> <li>• <u>Effusion</u>: 1+ or less is preferred (2+ acceptable if all other criteria are met) – Appendix C</li> <li>• <u>Weight Bearing</u>: Demonstrates pain-free ambulation without visible gait deviation</li> </ul>



<b>NMES Parameters</b> <i>(Appendix B)</i>	<ul style="list-style-type: none"> <li>• NMES pads are placed on the proximal and distal quadriceps</li> <li>• 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</li> <li>• 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</li> <li>• 20 seconds on/ 50 seconds off x 15 min</li> </ul>
<b>Goals to Progress to Next Phase</b>	<ol style="list-style-type: none"> <li>1. Full active quadriceps contraction with superior patellar glide</li> <li>2. Full passive knee extension</li> <li>3. Effusion <math>\leq</math> 2+ (effusion can at least be swept out of medial sulcus)</li> <li>4. SLR x 10 seconds without extensor lag</li> <li>5. Tolerates FWB without increased pain or 3+ effusion</li> <li>6. Walks without obvious gait deviations (may still use assistive device)</li> </ol>



## Phase IB: Protection (2-4 Weeks)

<b>Goals Phase IB</b>	<ul style="list-style-type: none"> <li>• Protect Repair</li> <li>• Reduce pain and inflammation</li> <li>• Achieve normal gait mechanics</li> <li>• Prevent muscle atrophy—regain active quadriceps contraction</li> <li>• No OKC strengthening until 4 weeks post-op</li> </ul>
<b>Gait</b>	<ul style="list-style-type: none"> <li>• NWBing in TROM immobilizer               <ul style="list-style-type: none"> <li>○ <b>However, this depends on the specific direction and type of osteotomy. ALWAYS refer to the operative note to confirm WBing status, or reach out to the surgical team for confirmation</b></li> </ul> </li> </ul>
<b>ROM</b>	<ul style="list-style-type: none"> <li>• Continue passive, active-assisted, and active ROM as tolerated               <ul style="list-style-type: none"> <li>○ No forced flexion beyond 90° with concomitant meniscal repair</li> </ul> </li> <li>• Intervention suggestions:               <ul style="list-style-type: none"> <li>○ Biking— no resistance, full revolutions</li> <li>○ Bag hangs (Appendix A)</li> <li>○ Patellar mobilizations—<b>NO</b> lateral mobilization (superior/inferior only)</li> </ul> </li> </ul>
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• Continue weeks 0-2</li> <li>• Quad Sets—long-sitting, prone, standing</li> <li>• SLR in flexion, abduction, adduction (if tolerated and appropriate) and extension               <ul style="list-style-type: none"> <li>○ Avoid extensor lag</li> </ul> </li> <li>• Continue NMES               <ul style="list-style-type: none"> <li>○ Multi-angle knee extensor isometrics from 60°-90° are also appropriate for those patients who cannot tolerate high-intensity NMES</li> </ul> </li> <li>• Hamstring activation—heel slides, hamstring sets, bridges</li> <li>• Begin trunk and lumbopelvic strengthening—planks, pelvic tils, abdominal bracing</li> <li>• BFR (continue as in early phase, adding appropriate exercises)</li> </ul>
<b>Pain &amp; Effusion</b>	<ul style="list-style-type: none"> <li>• Ice/cryotherapy, compression, elevation PRN to reduce effusion</li> </ul>
<b>Goals to Progress to next phase</b>	<ol style="list-style-type: none"> <li>1. Effusion: <math>\leq</math> 2+</li> <li>2. FWB without increased pain or effusion</li> <li>3. Ambulate on level surfaces without assistive device and with normal mechanics</li> <li>4. Single leg stance <math>\geq</math> 30 seconds without loss of balance</li> </ol>



## Phase IIA: Moderate Protection (4-6 Weeks)

<b>Goals Phase IIA</b>	<ul style="list-style-type: none"> <li>• Good quadriceps control</li> <li>• Controlled effusion</li> <li>• Improving tolerance to loading progression</li> </ul>
<b>Gait</b>	<ul style="list-style-type: none"> <li>• NWBing x 6 week in TROM immobilizer             <ul style="list-style-type: none"> <li>○ <b>However, this depends on the specific direction and type of osteotomy. ALWAYS refer to the operative note to confirm WBing status, or reach out to the surgical team for confirmation</b></li> </ul> </li> <li>• Gait training             <ul style="list-style-type: none"> <li>○ Focus on equal weight distribution bilaterally and normalization of gait mechanics</li> <li>○ Begin with 2 crutches, progress to 1 crutch, and then no support once gait mechanics are normalized</li> <li>○ Evaluate for symmetrical joint loading during stance phase, heel strike with full knee extension at initial contact, appropriate push-off at toe off</li> </ul> </li> </ul>
<b>ROM</b>	<ul style="list-style-type: none"> <li>• Continue passive, active-assisted, and active ROM as tolerated <i>**Concerns with limited ROM should be communicated directly with surgeon**</i></li> <li>• Higher grade superior/inferior patellar mobilizations and gentle overpressure to end ranges if ROM is a concern</li> <li>• Biking— light resistance</li> <li>• Continue with thigh and calf flexibility PRN</li> </ul>
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• Continue NMES</li> <li>• Resistance exercises for gluteal strengthening             <ul style="list-style-type: none"> <li>○ Resisted side-stepping and backward walking, clamshells, reverse clamshells</li> </ul> </li> <li>• Initiate OKC progression             <ul style="list-style-type: none"> <li>○ SAQ → LAQ (modified range → full range LAQ)</li> </ul> </li> <li>• Progress SL stability</li> <li>• Heel/toe raises</li> <li>• BFR (continue as in early phase, adding appropriate exercises)</li> </ul>
<b>Pain and effusion</b>	Ice/cryotherapy, compression, elevation PRN to reduce effusion
<b>Goals to Progress to Next Phase</b>	<ol style="list-style-type: none"> <li>1. Effusion: <math>\leq 2+</math></li> <li>2. FWB without increased pain or effusion</li> <li>3. Ambulate on level surfaces without assistive device and with normal mechanics</li> <li>4. Single leg stance &gt; 15 seconds without loss of balance</li> <li>5. Good volitional quad activation with TKE and no lag with SLR</li> </ol>



## Phase IIB: Moderate Protection (6-10 Weeks)

<b>Goals Phase IIB</b>	<ul style="list-style-type: none"> <li>• Achieve normal gait mechanics</li> <li>• Improve thigh and hip strength and neuromuscular control</li> <li>• Pain-free functional movements</li> </ul>
<b>Gait</b>	<ul style="list-style-type: none"> <li>• Open brace at ~6 weeks</li> <li>• Goal: Discharge brace completely with normal ambulation by 8 weeks post-op</li> <li>• Gait training             <ul style="list-style-type: none"> <li>○ Focus on equal weight distribution bilaterally and normalization of gait mechanics</li> <li>○ Begin with 2 crutches, progress to 1 crutch, and then no support once gait mechanics are normalized</li> <li>○ Evaluate for symmetrical joint loading during stance phase, heel strike with full knee extension at initial contact, appropriate push-off at toe of</li> </ul> </li> </ul>
<b>ROM</b>	<ul style="list-style-type: none"> <li>• Continue with stretching and bike PRN</li> </ul>
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• Continue NMES if indicated (See NMES d/c criteria below)</li> <li>• Shuttle/Leg Press—begin 90°-0° and progress per pain and technique             <ul style="list-style-type: none"> <li>○ Bilateral → single leg per patient tolerance and mechanics</li> </ul> </li> <li>• Squat progressions (DL and SL) on stable and unstable surfaces</li> <li>• Single leg stance—eyes open → eyes closed             <ul style="list-style-type: none"> <li>○ Progress to dynamic movements and/or unstable surface</li> </ul> </li> <li>• Progress WB strengthening exercises for quadriceps and hamstring per patient's tolerance             <ul style="list-style-type: none"> <li>○ Early phase: step ups, step downs (heel taps)—progress height as tolerated</li> <li>○ Late phase: SL RDL's, SL squats—begin partial range</li> </ul> </li> <li>• Continue to progress OKC interventions             <ul style="list-style-type: none"> <li>○ Begin sub-maximal leg extensions in protected range (90°- 45°)</li> </ul> </li> <li>• Endurance: low impact activities → treadmill walking, stepper, elliptical</li> <li>• BFR (continue as in early phase, adding appropriate exercises)</li> </ul>
<b>Pain &amp; Effusion</b>	Ice/cryotherapy, compression, elevation PRN to reduce effusion
<b>Functional Testing</b>	Isometric testing at 10 weeks
<b>Criteria to Discharge NMES</b>	<ul style="list-style-type: none"> <li>• &lt;20% quad deficit on isometric testing</li> <li><b>OR if Biodex machine is not available:</b></li> <li>• 10 SLR without quad lag</li> <li>• Normal gait</li> <li>• 10 heel taps to 60 deg knee flexion with good quality</li> <li>• 10 rep max on Leg Press and similar effort bilaterally</li> <li>• Inability to break quad MMT</li> </ul>
<b>Criteria to Progress to Next Phase</b>	<ol style="list-style-type: none"> <li>1. Effusion: ≤ 1+</li> <li>2. Tolerates therex program without increased pain or effusion grade</li> <li>3. Maintains full, pain-free ROM symmetric to uninvolved LE</li> <li>4. Normal patellar mobility without apprehension</li> <li>5. Demonstrates normal mechanics with CKC exercises (squats, lunges, etc) and early jumping activities (PWB on shuttle, step holds, double leg partial range, etc)</li> </ol>





## Phase III: Return to Function (10-12 Weeks)

<b>Goals Phase III</b>	<ul style="list-style-type: none"> <li>• Improve strength, balance, and endurance</li> <li>• Initiate plyometric and jogging progression once criteria are met</li> </ul>
<b>ROM</b>	Maintain ROM symmetric to uninvolved limb
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• FWB strengthening exercises               <ul style="list-style-type: none"> <li>○ Progress resistance and from stable to unstable surface as tolerated</li> </ul> </li> <li>• OKC knee extension exercises—progress as tolerated without pain</li> <li>• Begin B shuttle jumping <math>\leq 50\%</math> BW (shuttle, Total Gym, etc.)               <ul style="list-style-type: none"> <li>○ Emphasis on symmetry in takeoff and landing phase</li> </ul> </li> <li>• Plyometric progression and walk-jog progression once criteria are met (see below)</li> </ul>
<b>Pain &amp; Effusion</b>	<ul style="list-style-type: none"> <li>• Ice/cryotherapy, compression, elevation PRN to reduce effusion</li> </ul>
<b>Functional Testing</b> (Appendix E & F)	<ul style="list-style-type: none"> <li>• Isometric testing at 10 weeks</li> <li>• Isokinetic testing at 12 weeks</li> </ul>
<b>Criteria to Initiate Running and Jumping</b>	<ol style="list-style-type: none"> <li>1. <u>ROM</u>: full, pain-free knee ROM, symmetrical with the uninvolved limb</li> <li>2. <u>Strength</u>: Isokinetic testing 80% or greater for hamstring and quad at 60°/sec and 300°/sec</li> <li>3. <u>Effusion</u>: 1+ or less</li> <li>4. <u>Weight Bearing</u>: normalized gait and jogging mechanics</li> <li>5. <u>Neuromuscular Control</u>: Pain-free hopping in place</li> </ol>
<b>Goals to Progress to Next Phase</b>	<ol style="list-style-type: none"> <li>1. Effusion: <math>\leq 1+</math></li> <li>2. Maintains full, pain-free ROM symmetric to uninvolved LE</li> <li>3. Normal patellar mobility without apprehension</li> <li>4. Isometric or isokinetic quadriceps and hamstring strength <math>\geq 80\%</math> LSI</li> <li>5. Tolerates the ex program, including initial jogging progression, without increased pain or effusion grade</li> </ol>



## Phase IV: Return to Sport/Activity (12+ Weeks)

<b>Goals Phase IV</b>	<ul style="list-style-type: none"> <li>• Good multi-planar dynamic neuromuscular control, including plyometrics</li> <li>• Sport/activity-specific training—avoid post-activity soreness &gt;24 hours             <ul style="list-style-type: none"> <li>◦ Hopping, cutting, agility drills as appropriate</li> </ul> </li> <li>• Cardiovascular endurance fit for activity</li> <li>• Normal strength and flexibility of core and B LE</li> </ul>									
<b>ROM</b>	<ul style="list-style-type: none"> <li>• Maintain ROM symmetric to uninvolved limb</li> </ul>									
<b>Strengthening</b>	<ul style="list-style-type: none"> <li>• Emphasize performance of the quadriceps, hamstrings, and trunk dynamic stability</li> <li>• Emphasize muscle power generation and absorption</li> <li>• Focus on activities that challenge muscle demand in intensity, frequency, &amp; duration</li> <li>• Emphasize sport-specific and position-specific activities</li> </ul> <p><i>Consider:</i></p> <ul style="list-style-type: none"> <li>• DL and SL transitions</li> <li>• Various planes of movement</li> <li>• Changes of direction</li> <li>• Perturbations &amp; varied surfaces</li> <li>• Multiple muscle groups simultaneously</li> <li>• Quad Sets—long-sitting, prone, standing</li> </ul> <p><i>Examples:</i></p> <ul style="list-style-type: none"> <li>• SL hop downs from increasing height (up to 12" box)</li> <li>• SL hop-holds progressing from stable to unstable (i.e. Airex) surface</li> <li>• DL and SL hops progressing from stable to unstable (i.e. Airex) surface and progressing from unidirectional to changing direction (i.e. 90° turn)</li> <li>• Tuck jumps (focus on increasing multi-joint flexion during landing and holding stable position)</li> <li>• 90° to 180° hops and jumps</li> </ul> <ul style="list-style-type: none"> <li>• Begin agility exercises at 50-75% effort—utilize visual feedback to improve mechanics</li> </ul> <p><i>Examples:</i></p> <table border="0"> <tr> <td>◦ Side shuffles</td> <td>◦ Carioca</td> <td>◦ T, I, or box drill</td> </tr> <tr> <td>◦ Hopping</td> <td>◦ Figure 8's</td> <td>◦ Resisted jogging (Sport Cord) in straight planes</td> </tr> <tr> <td>◦ Zig zags</td> <td>◦ Back pedaling</td> <td></td> </tr> </table>	◦ Side shuffles	◦ Carioca	◦ T, I, or box drill	◦ Hopping	◦ Figure 8's	◦ Resisted jogging (Sport Cord) in straight planes	◦ Zig zags	◦ Back pedaling	
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◦ Hopping	◦ Figure 8's	◦ Resisted jogging (Sport Cord) in straight planes								
◦ Zig zags	◦ Back pedaling									
<b>Functional Testing</b> (Appendix E, F, G)	<ul style="list-style-type: none"> <li>• Isokinetic testing at 12 weeks and beyond</li> <li>• Functional hop testing at <math>\geq</math> 12 weeks and once LSI of 80% or greater is achieved</li> </ul>									
<b>Criteria to Return to Sports Participation</b>	<ol style="list-style-type: none"> <li>1. <u>ROM</u>: full, painfree knee ROM, symmetrical with the uninvolved limb</li> <li>2. <u>Strength</u>: Isokinetic testing 90% or greater for hamstring and quad at 60°/sec and 300°/sec</li> <li>3. <u>Effusion</u>: No reactive effusion <math>\geq</math> 1+ with sport-specific activity</li> <li>4. <u>Weight Bearing</u>: normalized gait and jogging mechanics</li> <li>5. <u>Neuromuscular control</u>: appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements</li> <li>6. <u>Functional Hop Testing</u>: LSI 90% or greater for all tests</li> <li>7. <u>Physician Clearance</u></li> </ol>									



## Appendix A: Bag Hang

*Emphasis on low load, long duration stretching*

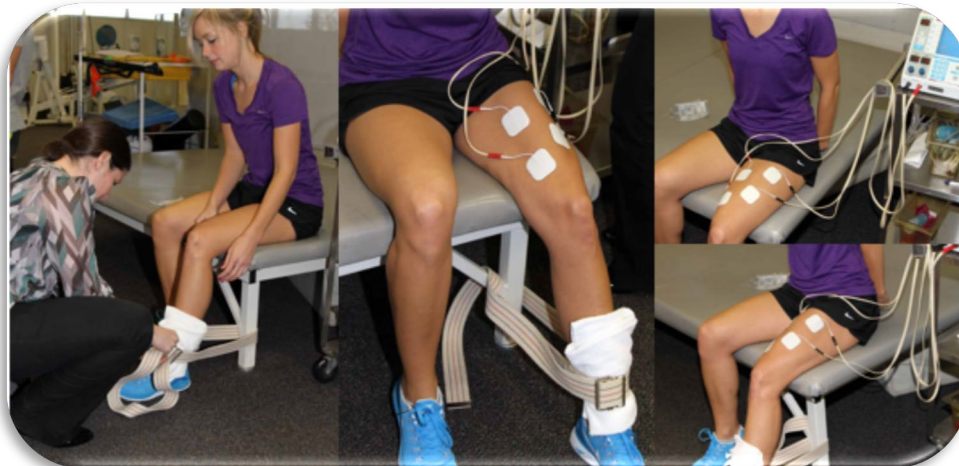
- Goal: 60 minutes of bag hang time total per day.
- Ideally: 4x15 minutes (or greater) per day



## 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

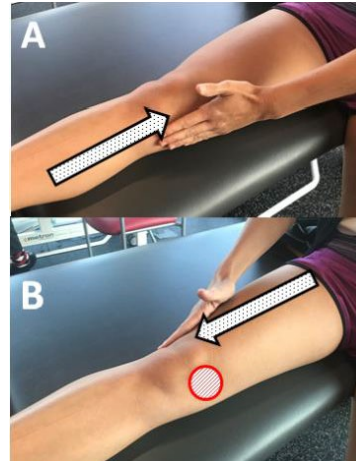


## Appendix C: Stoke Test / Swelling Assessment

### 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
<b>Red Light</b> 	<b>Yellow Light</b> 	<b>Green Light</b> 
<ul style="list-style-type: none"> <li>No running, jumping or cutting or heavy lifting until swelling decreases to 1+ or less</li> <li>Do not progress program until you speak with your therapist</li> <li>Utilize swelling management strategies (ice, compression, elevation, NSAIDs)</li> </ul>	<ul style="list-style-type: none"> <li>Proceed with caution</li> <li>You may participate in running, jumping and normal lifting routine.</li> <li>Check effusion before and after workouts</li> <li>Utilize swelling management strategies (ice, compression, elevation, NSAIDs)</li> </ul>	<ul style="list-style-type: none"> <li>May participate in running, jumping and normal lifting routine without restriction</li> <li>Continue to monitor swelling after activity</li> </ul>



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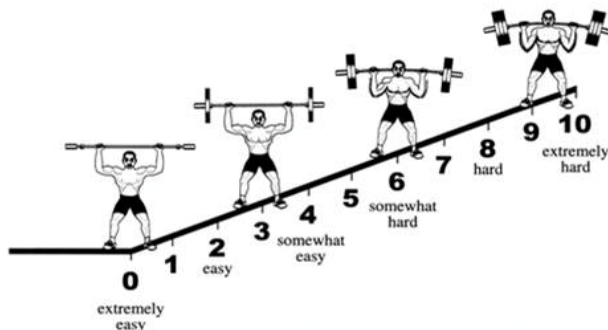
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## Appendix D: Blood Flow Restriction Training

Precautions (must get permission from MD)	Contraindications
<ul style="list-style-type: none"> <li>▪ 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)</li> <li>▪ Patients who are obese or with limb tissue that is loose</li> <li>▪ Arterial claudification</li> <li>▪ Abnormal clotting times</li> <li>▪ Diabetes</li> <li>▪ Sick cell trait</li> <li>▪ Tumor</li> <li>▪ General infection</li> <li>▪ Hypertension</li> <li>▪ Cardiopulmonary conditions</li> <li>▪ Renal compromise</li> <li>▪ Clinically significant acid-base imbalance</li> <li>▪ Atherosclerotic vessels</li> <li>▪ Taking anti-hypertensive medications</li> </ul>	<ul style="list-style-type: none"> <li>▪ Venous thromboembolism</li> <li>▪ Impaired circulation or peripheral vascular compromise</li> <li>▪ Previous revascularization of the extremity</li> <li>▪ Extremities with dialysis access</li> <li>▪ Acidosis</li> <li>▪ Sick cell anemia</li> <li>▪ Extremity infection</li> <li>▪ Tumor distal to the tourniquet</li> <li>▪ Medications/supplements known to ↑ clotting risk</li> <li>▪ Open fracture</li> <li>▪ Increased intracranial pressure</li> <li>▪ Open soft tissue injuries</li> <li>▪ Post-traumatic hand reconstructions</li> <li>▪ Severe crushing injuries</li> <li>▪ Severe hypertension</li> <li>▪ Elbow surgery with excessive swelling</li> <li>▪ Skin grafts in which all bleeding points distinguished</li> <li>▪ Secondary or delayed procedures after immobilization</li> <li>▪ Vascular grafting lymphectomies</li> <li>▪ Cancer</li> </ul>

**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
<b>A</b>	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>B</b>	Coefficient of Variance (%)	Between repetition variability	Goal: < 15%	If >15%, consider retest
<b>C</b>	Total Work (ft-lbs)	Torque over all repetitions	Possible indicator of fatigue	If >10%; consider high volume training
<b>D</b>	Agonist/Antagonist Ratio (%)	Hamstring/Quadriceps Ratio	Goal: >60%	<60%; ensure 1:1 quadriceps:hamstring exercise ratio
<b>E</b>	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

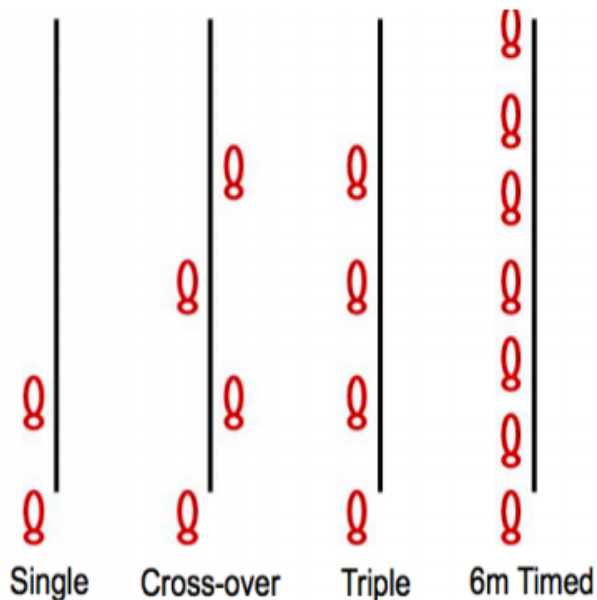
Sinacore, J. A., Evans, A. M., Lynch, B. N., Joreitz, R. E., Irrgang, J. J., & Lynch, A. D. (2017). Diagnostic accuracy of handheld dynamometry and 1-repetition-maximum tests for identifying meaningful quadriceps strength asymmetries. *Journal of orthopaedic & sports physical therapy*, 47(2), 97-107.

<p><b>Isokinetic Dynamometry</b></p>		<ul style="list-style-type: none"> <li>• Considered the “gold standard”</li> <li>• 60°/sec for strength and power assessment</li> <li>• 300°/second for speed and endurance assessment</li> </ul>
<p><b>Hand Held Dynamometry with Static Fixation at 90°</b></p>		<ul style="list-style-type: none"> <li>• Appropriate alternative</li> <li>• Results may overestimate quadriceps strength symmetry: be cautious with data interpretation</li> </ul>
<p><b>SL 1RM Knee Extension Machine: 90° - 45°</b></p>		<ul style="list-style-type: none"> <li>• Appropriate alternative</li> <li>• Recommended to decrease stress on PF joint and limit strain on reconstructed ACL for up to 6 months</li> <li>• Results may overestimate quadriceps strength symmetry: be cautious with data interpretation</li> </ul>
<p><b>SL 1RM Leg Press</b></p>		<ul style="list-style-type: none"> <li>• Fair alternative</li> <li>• Results in significant overestimation of quadriceps strength symmetry due to compensation from other LE muscle groups</li> </ul>
<p><b>SL 1RM Knee Extension Machine: 90° - 0°</b></p>		<ul style="list-style-type: none"> <li>• Fair alternative</li> <li>• May be uncomfortable and/or inappropriate due to PF stress</li> </ul>



## 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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