# 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

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| **Precautions** | • With concomitant procedures, range of motion or weight bearing precautions may be adjusted. These include:<br>  ○ Meniscal Repair: no forced flexion ROM beyond 90 degrees x4 weeks<br>  ○ Autologous Chondrocyte Implantation (MACI, NeoCart, NovoCart): full WB may be delayed to 8-12 weeks. ROM progression may be slowed<br>• ***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** | Medial Opening Wedge HTO:<br>• Weeks 0-2: TTWBing<br>• Weeks 2-4: 25% WB<br>• Weeks 4-6: 50% WB<br>• Weeks 6-8: WBAT with crutches<br>Anterior closing wedge HTO:<br>• Weeks 0-2: TTWBing<br>• Weeks 2+: progress to full WBing<br><br>WB progression may be delayed with a larger correction (>10 degrees or >10 mm correction)<br><br>***Please refer to the "post-op plan" section of the operative note or contact the surgeon for clarification*** |
| **Range of Motion** | • Week 0-2: 0-110°<br>• Week 2+: progress to full flexion ROM<br>*symmetrical knee extension should be achieved by week 4. If not achieved by week 4, contact surgeon. |
| **Outcome Tools** | Collect the LEFS at each visit<br><br>*You may choose to include IKDC, KOOS, ACL-RSI, Tegner or other questionnaires specific to your patient's needs* |
| **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** | • Isometric testing at 2-3 months<br>  ○ Delay to 4-5 months with concomitant ACI<br>• Isokinetic testing at 6, 9, 12 months and discharge<br>• Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing)<br>  ○ SL hop for distance<br>  ○ Triple hop<br>  ○ Cross over hop<br>  ○ Timed 6m hop<br>• **Functional strength testing and hop testing should be reserved for patients returning to high level activity** |
| **Criteria to Discharge Assistive Device** | • **ROM**: Full active knee extension; no pain on passive overpressure<br>• **Strength**: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag<br>• **Effusion**: 1+ or less is preferred (2+ acceptable if all other criteria are met)<br>• **Weight Bearing:** Demonstrates pain-free ambulation without visible gait deviation |

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| **Criteria to D/C NMES** | • <20% quad deficit on isometric testing<br>• If Biodex not available:<br>  ○ 10 SLR without quad lag<br>  ○ Normal gait<br>  ○ 10 heel taps to 60° knee flexion with good quality<br>  ○ 10 rep max on leg press and similar effort bilaterally<br>  ○ Inability to break quad MMT (5/5) |
| **Criteria to Initiate Running and Jumping** | • **ROM**: full, pain-free knee ROM, symmetrical with the uninvolved limb<br>• **Strength**: Isokinetic testing 80% or greater for hamstring and quad at 60º/sec and 300º/sec<br>• **Effusion**: 1+ or less<br>• **Weight Bearing:** normalized gait and jogging mechanics<br>• **Neuromuscular Control:** Pain-free hopping in place |
| **Criteria to Return to Sports Participation** | • **ROM**: full, pain-free knee ROM, symmetrical with the uninvolved limb<br>• **Strength**: Isokinetic testing 90% or greater for hamstring and quad at 60º/sec and 300º/sec<br>• **Effusion**: No reactive effusion ≥ 1+ with sport-specific activity<br>• **Weight Bearing**: normalized gait and jogging mechanics<br>• **Neuromuscular control:** appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements<br>• **Functional Hop Testing:** LSI 90% or greater for all tests<br>• **Physician Clearance** |
| **Return to Sport Expectation** | 6-12 months |

## RED/YELLOW FLAGS

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| **Red Flags**<br><br>*Require immediate referral for re-evaluation* | • Signs of DVT→ *Refer directly to ED*<br>  ○ Localized tenderness along the distribution of deep venous system<br>  ○ Entire LE swelling<br>  ○ Calf swelling >3cm compared to asymptomatic limb<br>  ○ Pitting edema<br>  ○ Collateral superficial veins<br>• Lack of full knee extension by 4 weeks post-op→*Refer to surgeon for re-evaluation*<br>• Mechanical block or clunk→*Refer to surgeon for re-evaluation*<br>• Reported episodes of instability→*Refer to surgeon for re-evaluation* |
| **Yellow Flags**<br><br>*Require modifications to plan of care* | • Persistent reactive effusion or pain following therapy or ADLs<br>  ○ *Decrease intensity of rehab interventions, continue effusion management, educate patient regarding activity modifications until symptoms resolve* |

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

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| **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** | • Week 0-2: 0-110 deg<br>• Week 2+: progress to full flexion ROM<br>**avoid active hamstring activity for first 2 weeks*<br>• Recommend ROM exercise as soon as possible after surgery to decrease articular swelling, scar tissue formation and joint stiffness<br>• Strong emphasis on patellar mobilizations (all directions) to regain full knee ROM<br>• **Contact MD by 4 weeks post op if ROM concerns** |
| **Weight Bearing** | Medial Opening Wedge HTO:<br>• Weeks 0-2: TTWBing<br>• Weeks 2-4: 25% WB<br><br>Anterior closing wedge HTO:<br>• Weeks 0-2: TTWBing<br>• Weeks 2+: progress to full WBing<br><br>**WB progression may be delayed with a larger correction (>10 degrees or >10 mm correction)**<br>***Please refer to the "post-op plan" section of the operative note or contact the surgeon for clarification*** |
| **Suggested Interventions** | • Ankle pumps<br>• Quadriceps, hamstring and gluteal isometrics<br>• Diaphragmatic breathing<br>• Effusion management strategies, including RICE<br>• Prone TKE<br>• SLR-4 way<br>• Patellar mobilization in all directions<br>• Gait training<br>• Extension ROM: Seated towel stretch, prone hang, bag hang<br>• Flexion ROM: heel slides, wall slides<br>  ○ Can progress to supine knee flexion with legs on ball, prone knee flexion after 2 weeks<br>• Recumbent cycling- for ROM only (week 2)<br>  ○ ½ circles→ full circles- lower seat as tolerated<br>• SAQ<br>• LAQ (through protected ROM (90-45 degrees)<br>• Clamshell<br>• Maintain hamstring and calf flexibility<br>• NMES in long sitting |
| **NMES Parameters** | • NMES pads are placed on the proximal and distal quadriceps<br>• Patient: Seated in long sitting (knees extended). Progress to 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<br>• 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 |

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| | • 20 seconds on/ 50 seconds off x 15 min |
| **Criteria to Progress to Early Loading Phase** | • Pain-free knee flexion of >120 degrees<br>• Pain-free and full passive knee extension<br>• Proficient heel-to-toe gait with 25% BW<br>• Reduced and well-controlled post-operative pain and edema<br>• Ability to perform a strong isometric quadriceps contraction (full tetany and superior patellar glide)<br>• Proficiency with home-exercise program |

## Phase II: Early Loading (4-8 Weeks)

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| **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** | Medial Opening Wedge HTO:<br>• Weeks 2-4: 25% WB<br>• Weeks 4-6: 50% WB<br>• Weeks 6-8: WBAT with crutches<br>Anterior closing wedge HTO:<br>• WBAT post-op day |
| **Suggested Interventions** | • Continue Phase 1 and 2 interventions<br>• Continue effusion management strategies<br>• SLR-Flexion progressions<br>  ○ Semi-reclined or seated<br>  ○ Add ER<br>  ○ Perform with eyes closed (cortical training)<br>  ○ Speed<br>  ○ Isometric holds at end-range<br>• Standing TKE<br>• Multi-Angle knee isometrics from 90-60 degrees<br>• Bridges<br>• Trunk stability interventions<br>  ○ TrA progression<br>  ○ Prone/side planks (modified-> full plank)<br>• Partial BW Shuttle Press (DL→SL)<br>• Closed Chain exercises: mini-squats, wall sits, heel raises, TKE<br>• OKC Knee Extension (90-30 deg ROM) (week 7+)<br>• OKC Hamstring strengthening (week 6+)<br>• Progress NMES to seated with tibia fixed at 60° of knee flexion |
| **NMES Parameters (with tibia fixed at 60° of knee flexion)** | • NMES pads are placed on the proximal and distal quadriceps<br>• 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<br>• 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<br>• 10-20 seconds on/ 50 seconds off x 15 min |

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| **Criteria to Discharge Assistive Device** | • **ROM**: Full active knee extension; no pain on passive overpressure<br>• **Strength**: Able to perform strong quad isometric with full tetany and superior patellar glide and able to perform 2x10 SLR without quad lag<br>• **Effusion**: 1+ or less is preferred (2+ acceptable if all other criteria are met)<br>• **Weight Bearing:** Demonstrates pain-free ambulation without visible gait deviation |
| **Criteria to Progress to Strengthening and Return to Function Phase** | • ROM: full and painless AROM and normalized PF mobility<br>• Effusion: <1+<br>• Strength: Quadriceps set with normal superior patellar translation, SLR x10" without extensor lag<br>• WB: able to tolerate CKC therex program without increased pain or effusion |

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

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| **Goals** | • Wean off crutches to normalized gait<br>• Progress functional balance/NM control<br>• Progress LE strengthening<br>• 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** | *Caution should be exercised when engaging in CKC knee flexion of approximately 90 degrees and stepping downstairs in early postoperative period<br>• Continue Phase 2 and 3 interventions as appropriate<br>• Multi-angle isometrics<br>• Balance and proprioception interventions<br>• BOSU Squats, lunges<br>• Mini squats: 0-45 degrees (week 8-10)<br>• Heel Taps: 2-4" (weeks 10-12)<br>• Step Ups: 6-8" (weeks 10-12)<br>• Resisted OKC quadriceps strengthening through full ROM (week 12-14)<br>• Lunges<br>• SL sit to stand, through protected ROM<br>• Core strengthening<br>• Conditioning:<br>  ○ Elliptical<br>  ○ Swimming<br>  ○ Outdoor cycling if desired (12+ weeks)<br>  ○ Rowing ergometry as tolerated<br>• Continue NMES until 80% symmetry is obtained<br>• Continue effusion management as needed |
| **Strength Testing** | • Isometric testing at 2-3 months<br>  ○ Delay to 4-5 months with concomitant ACI |
| **Criteria to Discharge NMES** | • <20% quad deficit on isometric testing<br>**OR if Biodex machine is not available:**<br>• 10 SLR without quad lag<br>• Normal gait |

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| | • 10 heel taps to 60 deg knee flexion with good quality<br>• 10 rep max on Leg Press and similar effort bilaterally<br>• Inability to break quad MMT |
| **Criteria to Progress to Return to Activity Phase** | • ROM: maintain full, pain free AROM<br>• Effusion: <1+<br>• Strength: Isometric or isokinetic quadriceps and hamstrings strength >/= 80%<br>• Weight Bearing: able to tolerate therapeutic exercise program, including jogging progression, without increased pain or >1+ effusion<br>• NM control: demonstrates proper lower extremity mechanics with all therapeutic exercises |

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

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| **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** | • Isometric testing at 2-3 months<br>  ○ Delay to 4-5 months with concomitant ACI<br>• Isokinetic testing at 6, 9, 12 months and discharge<br>• Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing)<br>  ○ SL hop for distance<br>  ○ Triple hop<br>  ○ Cross over hop<br>  ○ Timed 6m hop<br>**Functional strength testing and hop testing should be reserved for patients returning to high level activity** |
| **Suggested Interventions** | Performance of the quadriceps, hamstrings and trunk dynamic stability<br>• 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<br>• Single-leg squats on BOSU with manual perturbation to trunk or legs, Single-leg BOSU balance, single-leg BOSU Romanian deadlift<br><br>Once strength criteria have been met, perform the following progression:<br>• PBW jumping on the shuttle (DL → SL)<br>• Full body weight jumping progression<br>• Walk-jog program |
| **Criteria to Initiate Running and Jumping (4+ months)** | • **ROM**: full, pain-free knee ROM, symmetrical with the uninvolved limb<br>• **Strength**: Isokinetic testing 80% or greater for hamstring and quad at 60º/sec and 300º/sec<br>• **Effusion**: 1+ or less<br>• **Weight Bearing:** normalized gait and jogging mechanics<br>• **Neuromuscular Control:** Pain-free hopping in place |
| **Criteria to Progress to** | • Quadriceps and hamstring symmetry of 80% or greater |

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| **Return to Sport Phase** | • Ability to tolerate walking distances of 3 miles or greater without reactive pain or effusion<br>• Ability to effectively negotiate uneven ground, including soft sand, without reactive pain or effusion<br>• Ability to return to pre-operative low-impact recreational activities, including cycling, elliptical and weight training |

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

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| **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** | • Isokinetic testing at 6, 9, 12 months and discharge<br>• Hop testing (Appropriate after 80% symmetry achieved on isokinetic testing)<br>  ○ SL hop for distance<br>  ○ Triple hop<br>  ○ Cross over hop<br>  ○ Timed 6m hop<br>**Functional strength testing and hop testing should be reserved for patients returning to high level activity** |
| **Suggested Interventions** | • Continue progressive strength training per previous phases<br>Agility<br>  • Begin agility exercises between 50-75% effort (utilize visual feedback to improve mechanics as needed)<br>  • Advance plyometrics: Bilateral to single leg, progress by altering surfaces, adding ball toss, 3D rotations, etc.<br>  • Side shuffling, Carioca, Figure 8, Zig-zags, Resisted jogging (Sports Cord) in straight planes, backpedaling<br><br>Plyometrics<br>  • 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<br>Sport and position specific training |
| **Criteria for Return to Sport** | • **ROM**: full, pain free knee ROM, symmetrical with the uninvolved limb<br>• **Strength**: Isokinetic testing 90% or greater for hamstring and quad at 60º/sec and 300º/sec<br>• **Effusion**: No reactive effusion ≥ 1+ with sport-specific activity<br>• **Weight Bearing:** normalized gait and jogging mechanics<br>• **Neuromuscular Control:** appropriate mechanics and force attenuation strategies with high level agility, plyometrics, and high impact movements<br>• **Functional Hop Testing:** LSI 90% or greater for all tests<br>• **Physician Clearance** |

## Appendix A: Bag Hang

*Emphasis on low load, long duration stretching*

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

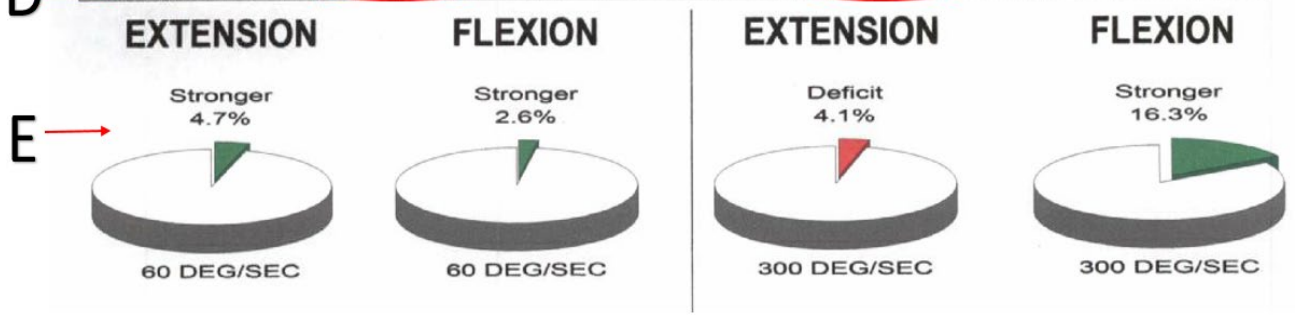
## Appendix B: NMES Set Up

*2 or 4 pad set-up is appropriate*

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

## Appendix C: Isokinetic Data Interpretation

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




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

## Appendix D: Isokinetic Testing and Appropriate Alternatives

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

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

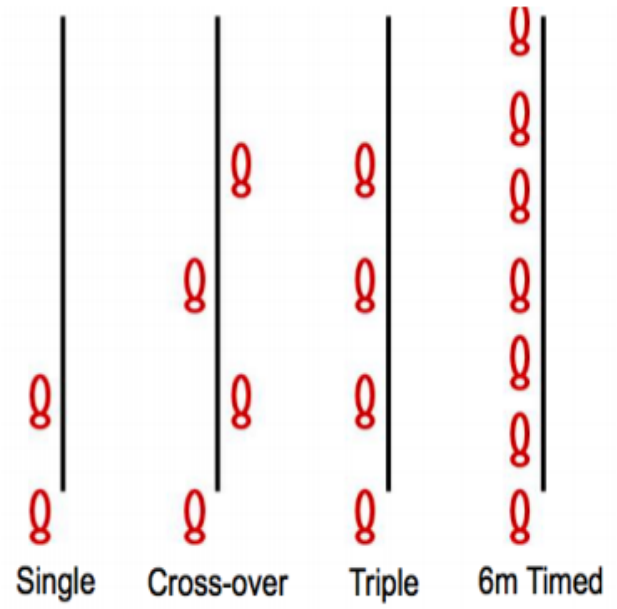
## Appendix E: Single Leg Hop Series

1) **Single hop for distance:** Have the subject line their heel up with the zero mark of the tape measure, wearing athletic shoes. The subject then hops as far as he/she can, landing on the same push off leg, for at least 3 seconds. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.

2) **Cross-over hop for distance:** The subject lines their heel up with the zero mark of the tape measure and hops 3 times on one foot, crossing fully over the center line each time. Each subject should hop as far forward as he/she can on each hop, but only the total distance hopped is recorded. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.

3) **Triple hop for distance:** The subject lines their heel up with the zero mark of the tape measure and hops 3 times on one foot. Each subject should hop as far forward as he/she can on each hop, but only the total distance hopped is recorded. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb distance/Uninvolved limb distance X 100%.

4) **Timed 6-meter hop:** The subject lines their heel up at the zero mark of the tape measure and hops, on cue with the tester, as fast as they can the length of the 6-meter tape. The arms are allowed to move freely during the testing. Allow him/her to perform 2 practice hops on each leg. Then, have the subject perform 2 testing trial, recording each distance from the starting point to the back of the heel. Average the distanced hopped for each limb. The Limb Symmetry Index: Involved limb time/Uninvolved limb time X 100%.



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## References

1. Noyes FR, Mayfield W, Barber-Westin SD, et al. (2006). Opening Wedge High Tibial Osteotomy: An Operative Technique and Rehabilitation Program to Decrease Complications and Promote Early Union and Function. *The American Journal of Sports Medicine*, 34(8), 1262-1273.
2. Brinkman JM, Lobenhoffer P, Agneskirchner JD, et al. (2008). Osteotomies Around the Knee: Patient Selection, Stability of Fixation and Bone Healing in High Tibial Osteotomies. *J Bone Joint Surg [Br]*, 90-b(12), 1548-1557.
3. Aalderink Kj, Shaffer M, Amendola A. (2010). Rehabilitation Following High Tibial Osteotomy. *Clin Sports Med*, 29, 291-301.
4. Lee DC, Byun SJ. (2012). High Tibial Osteotomy. *Knee Surg Relat Res*, 24(2), 61-69.
5. Morris J, Grant A, Kulkarni R, et al. (2019). Early Reults of Medial Opening Wedge High Tibial Osteotomy Using an Intraosseous Implant with Accelerated Rehabilitation. *European Journal of Orthopaedic Surgery& Traumatology*, 29, 147-156.
6. Wolcott M, Traub S, Efird C. (2010). High Tibial Osteotomies in the Young Active Patient. *International Orthopaedics (SICOT*), 34, 161-166.
7. Day M, Wolf B. (2019). Medial Opening-Wedge High Tibial Osteotomy for Medial Compartment Arthrosis/Overload. *Clin Sports Med*, 38, 331-349.
8. Lee OS, Ahn S, Lee YS. (2017). Effect and Safety of Early Weight-Bearing on the Outcome After Open-Wedge High Tibial Osteotomy: A Systematic Review and Meta-Analysis. *Arch Orthop Trauma Surg,* 137, 903-911.
9. Schroter S, Ateschrang A, Lowe W, et al. (2017). Early Full Weight- Bearing Versus 6-week Partial Weight Bearing After Open Wedge High Tibial Osteotomy Leads to Earlier Improvement of the Clinical Results: A Prospective, Randomised Evaluation. *Knee Surg Sports Traumatol Arthrosc*, 25, 325-332.
10. Sabzevari S, Ebrahimpour A, Roudi MK, et al. (2016). High Tibial Osteotomy: A Systematic Review and Current Concept. *Arch Bone Jt Surg*, 4(3), 204-212.
11. Kawazoe T, Takahashi T. (2003). Recovery of Muscle Strength After High Tibial Osteotomy. *J Orthop Sci*, 8, 160-165.
12. Seo H, Lim D, Jang YW, et al. (2018). Distribution of the Force in the Knee Joint during Daily Activities after Open Wedge High Tibial Osteotomy: A Rationale for the Proper Postoperative Management. *J Knee Surg*, DOI https://doi/org/10/1055/s-0038-1676772.
13. Nussbaum E, Houghton P, Anthony J, et al. (2017). Neuromuscular Electrical Stimulation for Treatment of Muscle Impairment: Critical Review and Recommendations for Clinical Practice. *Physiotherapy Canada* Special Issue, 69, 1-76.
14. Choi MY, Kong DH, Kim JS, et al. (2019). Rehabilitation Program After Medial Open Wedge High Tibial Osteotomy. *Arthrosc Orthop Sports Med*, 6(1), 1-8.
15. Minzlaff P, Feucht MJ, Saier T, et al. (2016). Can Young and Active Patients Participate in Sports after Osteochondral Autologous Transfer Combined with Valgus High Tibial Osteotomy? *Knee Surg Sports Traumatol Arthrosc*, 24, 1594-1600.
16. Ekhtiari S, Haldane CE, de SA D, et al. (2016). Return to Work and Sport Following High Tibial Osteotomy: A Systematic Review. *J Bone Joint Surg Am*, 98, 1568-1577.
17. Bauer S, Khan RJK, Ebert JR, et al. (2012). Knee Joint Preservation with Combined Neutralising High Tibial Osteotomy (HTO) and Matrix-Induced Autologous Chondrocyte Implantation (MACI) in Younger Patients with Medial Knee Osteoarthritis: A Case Series with Prospective Clinical and MRI Follow-Up Over 5 Years. *The Knee,* 19, 431-439.
18. Amendola A. (2007). Knee Osteotomy and Meniscal Transplantation: Indications, Technical Considerations, and Results. *Sports Med Arthrosc Rev*, 15(1), 32-38.