

Postoperative Rehabilitation and Return to Sport Following Multiligament Knee Reconstruction



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Abstract: Multiligament knee injuries (MLKIs) are debilitating injuries that increasingly occur in young athletes. Return to sport (RTS) has historically been considered unlikely due to the severity of these injuries. Reporting in the literature regarding objective outcomes following MLKI, including RTS, is lacking, as are clear protocols for both rehabilitation progressions and RTS testing. RTS following MLKI is a complex process that requires an extended recovery duration compared to other surgery types. Progressions through postoperative rehabilitation and RTS should be thoughtful, gradual, and criterion based. After effective anatomic reconstruction to restore joint stability, objective measures of recovery including range of motion, strength, movement quality, power, and overall conditioning guide decision-making throughout the recovery process. It is important to frame the recovery process of the athlete in the context of the severity of their injury, as it is typically slower and less linear. Improved reporting on objective outcomes will enhance our understanding of recovery expectations within this population by highlighting persistent deficits that may interfere with a full recovery, including RTS.

Multiligament knee injuries (MLKIs) are defined as a tear of 2 or more of the major knee ligaments, which include the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament or fibular collateral ligament (FCL).^{1,2} These devastating injuries are relatively uncommon, with more recent reports of 0.072 events per 100-patient years within the general population.^{1,3,4} MLKIs are often associated with knee dislocation, defined as a rupture of both cruciates with or without additional grade III injury to one of the collaterals.⁵ Disruption of the popliteal artery and/or

common peroneal nerve (CPN) constitutes a medical emergency that can have devastating consequences if unrecognized.⁶ MLKIs are seen more commonly in younger patients, with a mean age of 37 ± 15 years.^{7,8} The incidence of knee dislocation has been inversely correlated with age.^{7,8} MLKIs are often associated with high-energy trauma such as a motor vehicle accidents or fall from a height; however, nearly 50%, occur through a low-velocity mechanism, most commonly sport.^{9,10} Rates of MLKI caused by skiing sports and ball sports are as high as 29.4% and 6.9%, respectively. In the same cohort, motor vehicle accidents only accounted for 19.2% of all injuries.⁷

Given the severity of MLKI and the complexity of multiligament knee reconstruction (MLKR), return to sport (RTS) has historically been considered highly unlikely. RTS data have been inconsistent and incomplete, but existing evidence cites a RTS rate of 53%,¹¹ with competitive athletes having a lower RTS rate of 22%.¹¹ While surgical proficiency with MLKR has improved, RTS may be hindered by concerns regarding long-term joint health. MLKI patients show high rates of concomitant injury to articular cartilage (28.3%-48%) and menisci (37.3%-55%) at the time of initial injury and a high prevalence of radiographic osteoarthritis (OA) (23%-87%) following the injury.^{9,12-15} Poorer outcomes have been linked to meniscal pathology, cartilage pathology, and CPN palsy.¹⁶⁻¹⁸

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Fig 1. Prone passive range of motion.

Objective measures such as strength, balance, and power or laboratory-based reporting on functional movement patterns (squatting, hopping) are rarely reported within this population. These measures often form the central criteria for RTS decisions, as seen in the more common knee injury scenario of ACL rupture.¹⁹ The few studies investigating functional movement patterns following MLKI focus on gait. Only one study reports on quadriceps muscle strength.²⁰ Such measures are the pillars of healthy human movement and athletic function and are ill-defined in the existing MLKI literature, which makes it difficult to interpret reported outcomes such as the progression of knee OA or rates of RTS. Given the reported links between OA progression and quadriceps muscle weakness²¹ we cannot isolate MLKR as a singular causative factor for OA, but rather it is likely part of a spectrum of contributing factors which may include persistent muscular weakness and faulty movement patterns.

Effective early rehabilitation followed by appropriate progressions in both exercise program design and intensity are required for RTS, yet such rehabilitation guidelines specific to MLKI are sparse within the literature.^{22,23} In addition, specific guidelines for RTS within this population have not been defined with associated objective criteria. The purpose of this text is as follows: (1) define the rehabilitation process following MLKR, with an emphasis on end-stage

rehabilitation and RTS progressions; (2) define objective criteria, including descriptions of performance testing protocols, used to guide progressions through each phase of therapy, including re-entry into higher-level training and sport; and (3) describe current reported functional patient outcomes in more detail, including RTS, defining gaps in the literature, and areas for future research.

Postoperative Rehabilitation

Phase 1: “Recovery” (0-8 Weeks Postoperatively)

Initiation of rehabilitation on day 1 following surgical reconstruction has been reported to be safe and improves postoperative outcomes.²⁴ The primary goals in this earliest stage are limb protection (bracing and crutches), symptom management, protected range of motion (ROM), quadriceps muscle activation, and return to general wellness baseline (sleep, mood, energy, and nutrition). In addition, the clinician must monitor the patient closely for postoperative complications including arthrofibrosis, nerve injury (particularly the CPN),^{18,25-27} deep-vein thrombosis, or signs of occult vascular injury.²⁸⁻³¹

Cryocompressive therapy, elevation, manual lymphatic drainage, and compression garments may all be used to manage postoperative pain, joint effusion, and generalized limb edema.³²⁻³⁴ Non-weight-bearing is enforced for the first 6 weeks with gait with a knee immobilizer worn to protect the knee. Patients who undergo posterior cruciate ligament reconstruction (PCLR) transition into a dynamic PCL brace once swelling has sufficiently resolved to minimize posterior tibial translation (PTT) forces. Patients with other ligament reconstruction transition into a hinged brace once weight-bearing resumes.

Immediate joint ROM is safe²⁴ and crucial to reduce the risk of arthrofibrosis.^{35,36} Flexion is limited to 90° for the first 2 weeks to protect healing grafts. Passive ROM is recommended initially after PCLR, FCL reconstruction, or biceps femoris tendon repair to minimize PTT forces on the healing PCL grafts, reduce tension at the fibular head (where tunnel drilling and distal graft anchor occurs for FCL reconstruction), or to avoid direct pulling through the repaired biceps femoris tendon, respectively.^{37,38} ROM is performed in prone for the first 2 weeks after PCLR, also to reduce PTT due to tibial sag related to supine positioning (Fig 1). Stretching into knee hyperextension is initially discouraged following reconstruction of the PCL, FCL, or posterolateral corner (PLC) reconstruction to limit tension on grafts of structures that natively resist knee hyperextension.³⁹ It is critical, however, to restore full knee extension ROM.⁴⁰⁻⁴² Patellofemoral mobilizations are encouraged along with frequent quadriceps muscle contractions to limit the development of excessive

Table 1. Therapy Activity Progression Guidelines

Exercise Task	Minimum Time to Begin	Knee ROM Goals	Strength Goals	Ability Goals
Cycle with no resistance (with resistance)	6 wk (10 wk)	PROM extension 0°, flexion 120°		Able to rotate on bike
External loading application	12 wk			Tolerates single-leg body weight exercise
Basic footwork and jumping, OKC Hamstring, CKC exercise <70° KF	4 mo	AROM squat <70° KF	>65% quad LSI and PkTq/BW	25 SL squat from 60° KF at 60 bpm
Return to run progression	5 mo	Extension within 2°, flexion within 10°	75% quad LSI	90 Single leg pogo hops; anterior Y balance within 8 cm
Hopping, sprinting, cutting and pivoting progressions, sport specific tasks	6 mo	Extension full, flexion within 5°		25 SL squat from 90° at 60 bpm; anterior Y balance within 4 cm; Stress radiographs negative
Return to unrestricted training	9 mo	Extension full, flexion within 5°	90% quad LSI and PkTq/BW;	90%: SLH, TH, Y balance, SLDJ; T-test within norms

AROM, active range of motion; LSI, limb symmetry index; PkTq/BW, peak torque relative to body weight; PROM, passive range of motion; ROM, range of motion; SLDJ, single leg drop jump; SLH, single leg hop; TH, triple hop.

suprapatellar adhesions.⁴³ Early quadriceps activation is also crucial for restoring strength and mitigating atrophy.⁴³⁻⁴⁶ Open-chain resistive exercises are initially limited or modified, because quadriceps activation at greater than 60° knee flexion can induce PTT and less than 30° can induce anterior tibial translation, which may excessively load the healing grafts.^{37,38,47} Neuromuscular electrical muscular stimulation is encouraged for maximizing quadriceps muscle motor unit recruitment and has been shown to improve quadriceps function and outcomes following surgery.⁴⁴⁻⁴⁶ Blood flow restriction is a valuable modality used to mitigate muscle atrophy and strength loss and is shown to be safe and effective in appropriate populations.⁴⁸ By the end of this phase, patients should exhibit full knee extension and 110 to 120° of knee flexion, be able to perform consecutive repetitions of straight leg raising with no extensor lag, and demonstrate good tolerance for progressive intensity with other beginning strengthening exercises. This indicates readiness for weight-bearing progression and gait training.

Transition Phase: “Acclimation to Load” (8-10/12 Weeks)

The transition phase is the link between the Recovery and Rebuild phases. This phase has 2 main goals: (1) Progress to full weight-bearing with a non-antalgic gait pattern. (2) Prepare the joint to accept load to facilitate tolerance for future strength exercise progressions in subsequent phases. Patients acclimate to walking without crutches and may initiate basic weight bearing exercises. An effusion may still be present but must be nonreactive before phase progression.

Middle- and Late-Phase Rehabilitation: “Rebuild” and “Restore”

After the athlete successfully completes the transitional phase and tolerates basic joint loading, they can

proceed to the next phases of rehabilitation. The focus is now on fully resolving any remaining ROM deficits, initiating cardiovascular and work capacity training, re-establishing tolerance to joint and tissue loading, building muscle mass with progressive resistance exercise, and reintegrating the athlete into their sporting environment. Examples of therapy activity progressions can be found in Table 1.

All athletes may have the opportunity to return to sport following MLKI; however, the level of sport will depend on previous level of function, tolerance to rehab progressions, complexity of the injury and surgery, and the presence of nerve and/or vascular involvement with their initial injury. Realistic expectations should be discussed early in the recovery process. A CPN injury can affect lower extremity muscle function and recovery is typically slow, influenced by the initial injury severity, with 87.3% of patients with partial CPN palsy reported to experience a full functional recovery compared with only 38.4% of patients with complete palsy.⁴⁹ If complete palsy persists, a tendon transfer may be needed in the months following surgery to achieve some level of active dorsiflexion. Return to high-level cutting and pivoting following a tendon transfer may not be advised; however, certain sports (ie, downhill skiing) may be possible.

Individuals with a vascular injury experience worse long-term functional outcomes⁵⁰ and less flexion ROM following surgery.⁵¹ The effect of a vascular disruption on ligamentous healing is unclear, but it is the author's experience that these patients have increased post-operative laxity in general on stress radiographs compared with patients without a vascular injury. Articular cartilage health may be affected by MLKI and surgery. At a median of 12.7 years following a MLKR, radiographic OA was present in 42% of operated knees compared with only 6% on the contralateral side,⁹ although similar results have been seen following

Table 2. Sport Performance Testing Details and Goals

	Baseline (4 Months Postoperative)	Follow-Up 1 (7 Months Postoperative)	Follow-Up 2 (10+ Months Postoperative)
Basic clinical measures	<ul style="list-style-type: none"> • Knee joint ROM • Ankle joint ROM • Circumferential limb measures-muscle girth • Swelling measures • Hip strength with HHD (omit if s/p FCLR, PLCR) 	<ul style="list-style-type: none"> • Repeat baseline tests • Hip strength with HHD for all surgery types 	<ul style="list-style-type: none"> • Repeat baseline tests
Goals (for basic clinical measures)	Knee joint ROM: Extension 0°, flexion ≤10° SSD CKC ankle DF ROM: ≥40° DF, relative symmetry (≤5° SSD) Swelling: ≤1+ effusion Hip strength: ≥75% LSI	Knee joint ROM: Symmetrical extension, flexion ≤5° SSD Swelling: 0 effusion Hip strength: ≥85% LSI	Knee joint ROM: Symmetrical extension, flexion ≤5° SSD Swelling: 0 effusion Hip strength: ≥90% LSI (Raw scores within 10% of age/sex-matched norm values) Circumferential Measures: <2 cm SSD
Lower-extremity functional testing	<ul style="list-style-type: none"> • Y-balance test squat – anterior (Fig 5) • One leg rise test 	<ul style="list-style-type: none"> • Repeat baseline tests • Add: Hop tests as appropriate per recovery status (SLHD, THD) 	<ul style="list-style-type: none"> • Repeat baseline tests • Add/repeat: Hop tests (SLHD, THD)
Goals (for lower-extremity functional testing)	Y-balance: ≤8 cm SSD 1 leg rise test (from 60° KF) @ 60 bpm: able to complete 25 consecutive reps	Y-balance: ≤4 cm SSD 1 leg rise test (from 90° KF): able to complete 25 reps Hop testing: ≥80% LSI	Y-balance: ≤4 cm SSD (Raw score relative to limb length within 10% of age/sex-matched norm values) 1 leg rise test (from 90° KF): able to complete 25 reps Hop Testing: ≥90% LSI (Raw score within 10% of age/sex-matched norm values)
Biomechanics lab tests	<ul style="list-style-type: none"> • Isometric dynamometer quadriceps muscle strength 	<ul style="list-style-type: none"> • Repeat/add: Isometric quad strength, isokinetic quadriceps and hamstring muscle strength • Add: hop testing with motion capture over force plates as appropriate 	<ul style="list-style-type: none"> • Repeat: Isometric quad strength, isokinetic testing • Add/repeat: hop testing with motion capture over force plates
Goals (for lab tests)	Quad strength: ≥65-70% LSI ≥65%-70% peak torque/BW Squatting: (force plates, motion capture) Double leg squat: <10% loading asymmetry Single leg squat: >75° peak knee flexion angle	Quad strength: ≥80% LSI ≥75%-80% peak torque/BW Hamstring strength: ≥75% LSI Squatting/hopping: (force plates, motion capture) ≤10% loading asymmetry with bilateral vertical jump	Quad strength: ≥90% LSI ≥90% peak torque/BW Hamstring strength: ≥90% LSI Squatting/hopping: ≤10% loading asymmetry with bilateral vertical jump ≥75° peak knee flexion angle with SLFH landing Peak knee flexion angle (SLFH landing) within 90% of contralateral limb

BW, body weight; CKC, closed kinetic chain; DF, ankle dorsiflexion; FCLR, fibular collateral ligament reconstruction; HHD, hand-held dynamometer; KF, knee flexion; LSI, limb symmetry index; PLCR, posterolateral corner reconstruction; ROM, range of motion; SLFH, single-leg forward hop; SLHD, single-leg hop for distance; SSD, side-to-side difference; THD, triple hop for distance.

ACL rupture, as 60% to 90% of individuals will eventually present with radiographic evidence of OA.⁵² Higher quadriceps limb symmetry 5 years following an ACL reconstruction has recently been associated with a lower incidence of clinical knee OA,⁵³ highlighting the importance of sound rehabilitation and load progressions, especially for the quadriceps muscles within patients recovering from this more complex injury and surgery.

“Rebuild” (10 Weeks-6 Months)

At 10 weeks postsurgery, the rehabilitation emphasis changes from basic recovery from surgery to rebuilding the athlete’s knee in terms of biomechanics, proprioception, and movement patterns outside of linear gait progressions. Generalized weakness and muscular atrophy are still present, most notably at the quadriceps and hamstring muscles, due to non-weight-bearing status, postoperative arthrogenic



Fig 2. Knee over toes position with “kickstand” squat.

quadriceps inhibition, and the strict “hamstring-off” passive ROM precaution in the early phases. Therefore, loading progressions for regaining muscle strength and size are emphasized during this stage. Recovery goals for 4 months postoperative are listed in [Table 2](#).

Progressions

Before Four Months

If the athlete had a PCL or PLC reconstruction, open-chain hamstring strengthening is avoided. Hamstring activation beyond 30° of knee flexion induces PTT, which could be detrimental to a healing PCLR or PLC,³⁸ so strengthening from 6 weeks to 4 months involves submaximal effort exercises in shallow knee flexion angles. Open-chain quadriceps strength exercises are critical to isolate the muscle and recover strength. Closed-chain or weight-bearing quadriceps strengthening through squat, step-up, or lunge drills is initially limited to a depth of 70° of knee flexion to avoid the PTT that occurs in deeper squatting angles.^{54,55} Squat technique should ensure adequate knee over toe mechanics ([Fig 2](#)) to maximize quadriceps muscle activation, with gradual progressions that honor joint or tendon symptoms.

At Four Months

All postoperative exercise restrictions lapse. Hamstring exercises are progressed gradually per the required muscular demand of the exercise.⁵⁶ The Nordic hamstring exercise ([Fig 3](#)) is incorporated last due to the kneeling position and high levels of muscle activation, which can be contraindicated initially following PCLR. Athletes are now able to progress closed chain knee flexion loading (i.e., squatting) deeper than 70°. Single-leg loading is a focus of early strength training to minimize potential movement compensations, due to weakness, associated with double leg loading. Examples of closed-chain loading progressions are detailed in [Table 3](#).

Strengthening strategies are employed at various points along the force velocity curve, beginning with loaded isometrics, which are safe and nonirritating on the joint and can elicit strength improvements⁵⁷; exertion levels should progress over time. Eccentric and heavy slow resistance exercises, which include slow eccentric, isometric, and concentric phases, are incorporated next. Heavy slow resistance exercise has been shown to be beneficial for patellar tendinopathy⁵⁸; it is not uncommon for athletes who have had a patellar tendon autograft to experience some level of anterior knee pain, similar to patellar tendinopathy, following



Fig 3. Nordic hamstring exercise.

their MLKR. Blood flow restriction for the purpose of pain control can also be incorporated.⁵⁹ As strength and capacity improve, speed of movement increases, beginning with the concentric component. Loaded, quick movements with a shorter amortization phase are incorporated last.

Load Monitoring

Once external loads are tolerated, the overload principle is applied by progressively increasing load over time to increase strength.⁶⁰ Traditional periodization concepts are applied in early phases with greater repetition counts and lower loads, and later phases with lower reps and greater load; however, additional strategies outside the periodization framework have value. To maximize the effectiveness of each lifting session, self-monitoring parameters, commonly referred to as “autoregulation,” are used. Subjective ratings of perceived exertion and repetitions in reserve following a set as well as velocity-based training methods have shown to be useful to tailor workout intensity per recovery between sets.^{61,62} This type of training allows for real-time load adjustments to achieve the resistance necessary to attain maximum effort.^{61,62} Strict adherence to a traditional preplanned periodization model may be less important⁶³ than more precisely manipulating load to approach muscular failure within an exercise.^{64,65}

Cardiovascular and Work Capacity Training

Early initiation of work capacity and energy system development is vital for general activity preparedness and to gradually increase tolerance to repeated exercise bouts at a progressively greater capacity, as required for sport. Exercise sessions should progress in duration, intensity and work to rest ratios, while avoiding single session or weekly spikes in volume of work completed.⁶⁶ Workout intensity can be monitored through exertion scales or other means (i.e., wearable technologies). Intensity should increase gradually for safe and successful return to pre-injury activity and conditioning levels.⁶⁷

Rate of Force Development

The ability to produce maximum force is different than producing force at a high rate. Preinjury strength levels have been shown to return sooner than rate of force development (RFD) following ACL reconstruction,⁶⁸ so a similar, if not greater, delay or depression in recovery of RFD is likely following MLKR. RFD training can begin as early as 4 months postoperation and can progress from higher speed “making” isometrics to quick concentric or eccentric “braking” activities using the stretch-shortening cycle. The importance of RFD, including more comprehensive training descriptions, have been described in detail elsewhere.⁶⁹

Sensorimotor Training

ACL injury has been shown to alter the nervous system’s ability to interpret somatosensory information, causing heavier reliance on visual feedback, so it is expected that a MLKI will have equal or more somatosensory deficits.⁷⁰ Principles of motor learning are incorporated into all stages of rehabilitation to normalize nervous system functioning. An external focus of attention is a primary guiding strategy where the athlete is asked to focus on something other than their knee while performing an exercise. An external focus can expedite learning by facilitating automatic movements and thus depressing intracortical inhibition of voluntary muscle activation.⁷¹ Simple cognitive distractions like verbalizing a color or number displayed on a cell phone app, or having the athlete count backwards simultaneously with exercise, can begin early in recovery.

“Restore” (6 Months to 1+ Year)

The care plan following MLKR is typically extended, with increased time off school or work and an increased strain on resources such as insurance coverage, economics, transportation, and in-home support.⁷²⁻⁷⁴ The layout and duration of the Restore phase will vary, depending on the level of sport, the ability to continue with frequent rehabilitation visits, and the level of involvement of secondary providers. If an athlete is competing at the high school, collegiate, or professional level, coordination with their athletic trainer and strength coach is important as physical therapy visits taper in frequency. Small group training sessions, outside of insurance-covered therapy appointments, have become a popular option to provide supervised, higher-level training progressions in the later phases of recovery. The downside of this practice is the potential exclusion of athletes with fewer economic resources.⁷⁴

Return to Run and Sprint

A return to running progression begins once the athlete attains sufficient quadriceps strength, masters preparatory running drills, and meets performance targets with clinical testing (Table 2). Recently, Iwame et al.⁷⁵ reported that those individuals who met a cutoff value for quad strength divided by body weight of 1.45 Nm/kg had success with return to jogging, highlighting the importance of strength for normal running gait. A minimum period of 4 weeks with a jogging buildup program should be completed before the initiation of straight-line sprint progressions.⁷⁶

Progressions

Transition from linear movements to change of direction tasks should begin with rounded turns, then gradually move to sharper angled cutting and greater speeds. Cognitive demands and sport-specific tasks are

Table 3. Closed-Chain Loading Activity Progression Examples

Examples of Closed-Chain Exercise Tasks	Minimum Time to Begin	Functional Prerequisites	Sets (Surgical: Nonsurgical), Reps (Surgical: Nonsurgical), Hold Time
Forward lunge ISO hold over a step	8 wk	30 reps straight leg raise with no lag	1-2 (1:1), 2-10 (1:1), 5-30 second isometric
Single-leg kickstand (Fig 2) or split squat with body weight	10 wk	Athlete feels muscle activation more than knee irritation	1-2 (1:1), 2-10 (1:1), 5-30 seconds
Single-leg kickstand squat with dumbbell or kettlebell external load	12 wk	Athlete feels muscle activation more than knee irritation	2 (1:1), 12 (1:1), 2-30 second phases eccentric/isometric/concentric
Single-leg kickstand squat with Hex/safety/barbell straight bar external load	5 mo	75% quad LSI	2-4 (4:2), 12 (1:1), 2-6 second phases eccentric/isometric/concentric
Single and double leg loading	7 mo		3-5 (5:2), 4-8 (1-2:1), 0-3 seconds
Single- and double-leg loading	9 mo	90% quad LSI and PkTq/BW	3-5 (5:2), 2-5 (1-2:1), 0-3 seconds

ISO, isometric; LSI, limb symmetry index; PkTq/BW, peak torque relative to body weight.

incorporated per readiness. The “control-chaos continuum,” as described by Taberner et al.,⁷⁷ progresses the athlete from slow, controlled preplanned movements to fast, chaotic reactive sport-specific movements in the “on-field” environment. As the athlete moves through the Restore phase, they should see an increasing volume of load, skill, and physical fitness training while alternating difficult days with easier days to allow for recovery.⁷⁸ If an athlete returns to sport without having the capacity to do so, they are at a greater risk of injury.⁷⁹ As such, sport-specific training and within-sport participation is incorporated on a gradual continuum.

Testing for RTS

While there is no solid agreement on the best RTS criteria, a battery of tests including objective strength testing, single-leg hop testing and validated subjective questionnaires is advocated to assess overall readiness.^{80,81} Our MLKI RTS testing protocol (Table 2) mimics those used within the ACL population, as protocols specific to MLKI have yet to be defined or validated. Testing at our center is performed at 4, 7, and 10 months after surgery. Typical RTS testing time points are at 3, 6, 9 months,⁸²⁻⁸⁴ but the increased trauma and restrictions during early rehabilitation in this population warrants testing at later time points.

Strength Testing

Measurement of muscle function, specifically isolated quadriceps performance, can reveal deficits otherwise disguised though compensation strategies within functional movement testing. Our center tests both isometric and isokinetic strength using an isokinetic dynamometer. Quadriceps isometric strength is evaluated at 90° of knee flexion (Fig 4) at each time interval, while isokinetic quadriceps and hamstrings strength is evaluated at 60 deg/s at only the 7- and 10-month test intervals due to the hamstring precautions in early rehabilitation. A goal of >90% limb symmetry index is recommended for both quadriceps and hamstring strength at time of RTS.^{81,85} Relative

strength (strength compared with an athlete’s body weight) has shown to be a good predictor of patient-reported knee function and may be a better indicator for dynamic knee–joint stability and absorption of joint loads during activity.^{80,86} A goal of quadriceps isometric strength ≥ 3.0 Nm/kg is established within our MLKI RTS criteria.

Lower-Extremity Functional Testing

A number of tasks have been used to assess kinematic and kinetic compensation strategies in athletes after injury, such as double-leg squat, single-leg squat (SLS), double-leg jump, and single-leg forward hop



Fig 4. Quadriceps strength testing on an isokinetic dynamometer.



Fig 5. Y-balance squat test - anterior reach.

(SLFH).^{80,85,87,88} Specifically, altered landing mechanics have been shown to be an important predictor of ACL reinjury.⁸⁹⁻⁹¹ Therefore, examining these same mechanics within the MLKI population is of interest. The goal for MLKI athletes is to exhibit less than a 10% deficit in SLFH distance and peak knee flexion during both SLS and SLFH landings. In addition, the surgical limb should achieve deep knee flexion, defined as $>75^\circ$, during peak knee flexion in SLS and SLFH landings. Asymmetrical limb-loading and decreased functional knee stability have been shown to be associated with quadriceps weakness and likeliness to RTS^{92,93}; therefore, it is important for MLKI individuals to restore excellent limb symmetry when returning to activities.

Subjective Testing

Subjective patient-reported outcome measures (PROMs) have become increasingly popular in predicting RTS.^{86,94} The Knee injury Osteoarthritis Outcome Score, International Knee Documentation Committee 2000 Subjective Knee Form, and the ACL-Return to Sport after Injury are traditional PROMs consistently reported in ACL literature and have shown to be strongly associated with RTS objective measures.^{90,95-97} The ACL-Return to Sport after Injury, validated within the ACL population, includes questions regarding emotional well-being, physical performance confidence, and appraisal of risk. According to Sadeqi et al.,⁹⁵ those who score ≥ 60 at 6 months postsurgery will likely return to the preinjury level at 2 years after surgery. Greater confidence in performance combined with less fear have been shown to distinguish those who do and do not RTS.^{96,98} No PROMs have been validated in the MLKI population. Studies including Knee injury Osteoarthritis Outcome Score and International Knee Documentation Committee 2000 Subjective Knee Form outcomes often report on

data collected years after surgery and are not specific to RTS.^{99,100}

RTS: Clinician Guidelines and Reported Outcomes

This step will look different for each athlete depending on their surgery, previous level of function, and goals. ACL reconstruction literature has shown that returning to sport before 9 months may lead to a greater rate of reinjury.^{82,101} Similar research regarding recommended RTS timelines does not exist specific to MLKR. At our center, athletes are educated that return to play will likely take 12 to 18 months. Managing expectations is important in this population, given poor existing reports on RTS (53% of patients with MLKR return to any level of sport, and 22% return to high-level sport).¹¹ The specific ligaments involved may make a difference as well. Fifty athletes from the National Football League were observed following MLKR to find that 70.8% of ACL/MCL tears and 55.6% of ACL with PCL or FCL involvement returned to play at 305.1 ± 58.9 and 459.2 ± 245.1 days, respectively. Return to previous performance was 43.5% for ACL/MCL and 18.5% for ACL with PCL or FCL. In comparison, a case series of 165 National Football League athletes reported an 82.4% return to play rate when undergoing an isolated ACL reconstruction.¹⁰²

The majority of MLKI literature agrees that fear of reinjury was the biggest contributor to not returning to competitive sports.¹⁰³ A variety of clinical and laboratory objective tests are essential for safe return to play decision-making,³⁹ and MLKI research lacks both foundational objective measures and population specific validated PROMs. Only one study was found that measured strength, reporting 84% quadriceps and 90% hamstring limb symmetry indices at 24 months postoperatively.²⁰ These quadriceps strength outcomes at 2 years postoperatively are substandard and raise concern, as most athletes seek to return to sport within 12 months from surgery. To our knowledge, no study has examined jumping or hopping performance following MLKR. Only gait analyses have been conducted, however, often years after surgery. MLKI patients exhibited slower gait, shorter steps, and altered knee kinematics compared with healthy controls.¹⁰⁴⁻¹⁰⁷ Our RTS testing protocol, including goal values, is illustrated in [Table 2](#).

Conclusions

MLKIs can be debilitating for athletes. Historically, return to play after a MLKI has been out of the question; however, with the advancement of surgical proficiency using an anatomic reconstruction, the prognosis for recovery following MLKI has changed.²⁴ With the initiation of rehabilitation on day 1 after surgery, effective progressions through a

comprehensive rehabilitation process, and realistic expectations regarding timelines, RTS is possible. It is important to consider the extent of the injury to set appropriate expectations for recovery and RTS. Objective outcomes reporting and guidelines for rehabilitation progressions to return an athlete to sport following MLKR are lacking. RTS testing following MLKR should be criterion based and use a combination of strength, functional, and subjective testing. The rehabilitation process following MLKR is typically slower overall, and RTS phases will be longer. The process can be physically and mentally taxing for the patient and practitioner; however, by following a conservative approach with deliberately cautious phase progressions a successful, safe return to sport is possible.

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