

Clinical Commentary/Current Concept Review

Current Concept Review: Medial Patellofemoral Ligament Reconstruction: From Rehabilitation to Return to Sport

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Medial patellofemoral ligament (MPFL) reconstruction is a surgical procedure to improve the clinical outcomes for recurrent patellar dislocation. Current literature on MPFL reconstruction lacks the details on rehabilitation protocols and the criteria for clearance to sports participation. Additionally, research on biomechanical deficits after MPFL reconstruction remains limited, and psychological factors influencing return to sport (RTS) are often underemphasized. A comprehensive approach integrating clinical criteria, biomechanical assessments, and psychological considerations may optimize rehabilitation outcomes and RTS success. The purpose of this clinical commentary is to provide a comprehensive review of current literature in MPFL reconstruction rehabilitation and outcomes. This commentary will review published rehabilitation protocols to outline phase-specific guidelines. Current literature related to biomechanical characteristics, patient-reported outcomes, impairment and performance-based outcomes and psychological measures will be summarized. Finally, RTS guidelines with objective criteria will be provided.

Level of Evidence

Level 5

INTRODUCTION

Patellar dislocation is a common injury typically caused by a knee flexion-rotation mechanism, resulting in a lateral dislocation of the patella and subsequent medial patellofemoral ligament (MPFL) deficiency or rupture.¹ Primary patellar dislocation is often managed with nonoperative treatment which typically requires a period of immobilization followed by physical therapy.² In cases of recurrent patellar dislocation and/or accompanying injuries, surgical management is recommended to restore patellofemoral joint stability, especially in patients who anticipate returning to a high level of sports participation.^{3,4} Among surgical management options, MPFL reconstruction is an effective procedure with demonstrated improvements in clinical and functional outcomes for those who experience recurrent patellar dislocation.^{5,6} Achieving successful outcomes after

MPFL reconstruction requires adherence to post-operative rehabilitation. However, current literature on MPFL reconstruction lacks the necessary details for clinicians to fully implement the rehabilitation protocols and varies greatly among different surgical techniques. Therefore, proposing phase-specific guidelines in MPFL reconstruction rehabilitation for clinicians to follow is important.

The goal of post-operative rehabilitation after MPFL reconstruction is to restore normal knee function and allow full return to functional/sports activities. Many patient-reported outcomes with high validity and reliability have been developed to use in populations who have undergone knee surgery.⁷ Appropriate selection of patient-reported outcomes can provide insight into the patient's perception on the recovery of knee function during the course of post-operative rehabilitation. Beyond patient-reported outcomes, biomechanical characteristics and performance dur-

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ing functional tasks offer objective assessments of knee function and may help determine a patient's readiness to return to sport (RTS). However, standardized RTS criteria following MPFL reconstruction remain undefined. In contrast to anterior cruciate ligament (ACL) reconstruction, where limb symmetry benchmarks and hop test outcomes serve as established RTS guidelines, no consensus exists for MPFL reconstruction. Additionally, injury-related psychological distress could hinder a successful RTS post-operatively. A retrospective review of patients who underwent MPFL reconstruction indicated that 40% of patients were unable to RTS due to fear of re-injury while 14% were unable due to lack of confidence.⁸ Identifying patients with elevated psychological distress and incorporating a psychologically-informed approach into clinical practice may maximize rehabilitation functional outcomes.

The purpose of this commentary is to provide a comprehensive review of current literature in MPFL reconstruction rehabilitation and outcomes. The commentary will review published rehabilitation protocols to outline phase-specific guidelines, including the protection phase, strengthening phase, advanced strengthening and functional phase, and RTS phase. Current findings related to biomechanical characteristics, patient-reported outcomes, impairment and performance-based outcomes, and psychological measures will be summarized. Finally, RTS guidelines with objective criteria will be provided.

EVIDENCE ACQUISITION

A PubMed search was conducted for publications relating to MPFL reconstruction from 1994 to 2023, using keywords including "patellar dislocation", "MPFL reconstruction", "rehabilitation", "outcome" and "RTS". Reference lists of retrieved articles were also searched for additionally relevant articles. This review included peer-reviewed publications focusing on rehabilitation protocols and RTS outcomes. Case reports, expert opinions, non-peer-reviewed articles and non-English studies were excluded to maintain quality and consistency.

PATELLAR DISLOCATION

Patellar dislocation predominantly affects adolescents with an annual incidence of 43 per 100,000,⁹ with a peak incidence occurring between 15 and 19 years of age.¹⁰ Nearly half (51.9%) of all patellar dislocation occurred during sport participation.¹⁰ The relationship between sex and incidence of patellar dislocation remains inconsistent, with some studies reporting a higher prevalence in females,⁹ while other studies indicate that incidence of patellar dislocation does not significantly differ between males and females.^{10,11} In terms of laterality, patellar dislocation associated with acute trauma is more commonly observed unilaterally. Conversely, bilateral instability is more frequently linked to structural and anatomic abnormalities, such as trochlear dysplasia and patella alta.^{12,13}

MPFL RECONSTRUCTION AND CONCOMITANT PROCEDURES

Patellar dislocation is a multifactorial condition influenced by traumatic, anatomical, and biomechanical factors. Surgical management for recurrent patellar dislocation is tailored to the underlying failure mechanism to restore stability and prevent recurrence. The procedure may involve MPFL reconstruction alone or in combination with other procedures to improve patellar tracking and medial patellofemoral stability. Soft tissue procedures, such as lateral retinacular release (release tension of the lateral retinacular) and vastus medialis advancement (reposition and tighten the vastus medialis) can help improve dynamic patellar control. In cases with bony abnormalities, tibial tubercle osteotomy (realign/reposition the tibial tubercle) and trochleoplasty (reshape the trochlear groove of the femur) are performed in conjunction with MPFL reconstruction to optimize joint congruency and stability.^{12,14} Chondroplasty (debridement or smoothing the surface of damaged cartilage) may also be performed if patellofemoral cartilage damage is present. For skeletally immature patients, the modified Roux-Goldthwait procedure can be utilized to transfer the lateral half of the patellar tendon medially, securing it to the tibia to enhance patellar stability without disturbing open growth plates.^{5,15,16}

Overall, isolated MPFL reconstruction with or without additional stabilization procedures results in similar favorable clinical outcomes.^{17,18} Surgical techniques for MPFL reconstruction vary, particularly in graft selection and fixation methods. Autografts may be harvested from the semitendinosus, gracilis, adductor magnus, quadriceps, or patellar tendons, while allografts are commonly from the semitendinosus or gracilis tendons. The Schöttle point on the femur serves as the preferred fixation site, replicating the anatomical origin of the native MPFL.¹⁹ Common femoral fixation techniques include endobutton, interference screws, and suture anchors.²⁰ Consensus on the optimal graft type or femoral fixation technique has not been established.¹⁵ Current evidence indicates that no significant differences are observed in clinical outcomes, such as pain level, self-reported function, knee strength and rates of RTS, across different graft types.²¹⁻²⁴ The overall rates of recurrent patellar dislocation after isolated MPFL reconstruction across adult and adolescents patients are below 2% regardless of graft (autograft [0%-20%], allograft, synthetic graft [0%-3.3%]) selection.²⁵ Commonly reported complications after MPFL reconstruction include pain, persistent apprehension without instability, patellar fracture, joint stiffness and post-operative infection.^{5,25-28}

RANGE OF MOTION (ROM) AND WEIGHT-BEARING RESTRICTIONS

To ensure graft protection, it is important to follow ROM and weight-bearing restrictions after MPFL reconstruction. While the variability in allowable ROM and weight-bearing restrictions exists between surgeons, many prefer a period of immobilization with gradual increases in flexion over the first 4-6 weeks and restrict weight-bearing initially with

the use of an assistive device then gradual progress to full weight-bearing.²⁹ The literature generally suggests aiming for full knee flexion between 4 to 12 weeks post-operatively and full weight-bearing from 0 to 8 weeks.^{6,30-32} Surgeons often advise using a knee brace along with an assistive device during early ambulation. The duration for brace use varies widely across different protocols, ranging from 0 to 12 weeks.^{30,33}

PHASE-SPECIFIC GUIDELINES

The overarching goal of MPFL reconstruction rehabilitation is to address the impairments after MPFL reconstruction and facilitate safe return to prior level of function and sport. The proposed rehabilitation protocol is intended to provide a guideline for clinicians to progress through phases based on meeting clinical criteria. This rehabilitation protocol includes four phases (1) the protection phase, (2) the strengthening phase, (3) the advanced strengthening and functional phase, and (4) the RTS phase ([Table 1](#)).²⁹

THE PROTECTION PHASE

The protection phase (week 0-6 post-surgery) should focus on diminishing pain and swelling, gradually increasing knee flexion ROM, restoring full knee extension, and improving quadriceps control (straight leg raises without extension lag). The milestones of the protection phase are knee flexion greater than 110°, full knee extension, straight leg raise without extension lag, and walking without crutches.^{29,31,34}

As pain and swelling are known to inhibit quadriceps muscle control, cryotherapy, elevation and compression can be used to alleviate pain and reduce swelling.^{35,36} ROM should be initiated within the first two weeks of surgery and progressed per surgeons' protocol. Typically, patients start 0°-30° in the first or second week and progress by 20°- 30° per week. Knee extension deficit is a frequently observed issue after knee surgery, which can contribute to functional deficits and potentially increase the risk of osteoarthritis in the long term.³⁷ Long duration stretching, such as heel props and prone hangs, are effective exercises to improve knee extension.³⁸ The application of neuromuscular electrical stimulation (NMES) during ACL reconstruction rehabilitation has shown to improve quadriceps activation and strength.³⁹ The use of NMES could be considered during early stages after MPFL reconstruction to facilitate quadriceps activation. Exercises including quadriceps setting and straight leg raise should be started immediately after the surgery to improve quadriceps control. Lower body strengthening exercises, such as bridges and clamshells, can enhance hip abduction and external rotation strength, supporting knee alignment in later rehabilitation phases.

As MPFL reconstruction is not affected by the axial loading of the knee joint, weight-bearing following the surgery is usually not limited.⁴⁰ However, modifications to weight-bearing status may be made if a concurrent procedure is performed during the surgery, such as tibial tubercle osteotomy or chondral restoration procedures.^{29,41} Early weight-bearing should be encouraged and gradually pro-

gressed to full weight-bearing. As patients progress in tolerance to weight-bearing tasks, weight shifting exercises and double/single-leg balance tasks can be incorporated into the treatment sessions. A hinged knee brace is commonly recommended post-operatively to protect the knee from rotational stress,⁴⁰ which may compromise the graft site fixation and maturation. However, recent research indicates that accelerated rehabilitation without weight-bearing restrictions or immobilization (no post-operative knee brace) following isolated MPFL reconstruction may facilitate a more rapid recovery of quadriceps control⁴² without increasing the risk of recurrence.⁴³ These findings suggest that patients undergoing isolated MPFL reconstruction might safely begin early unrestricted weight-bearing, promoting early strengthening of quadriceps.

THE STRENGTHENING PHASE

The strengthening phase (week 6-12 post-surgery) should focus on restoring full knee flexion and improving knee muscle strength. The milestones of the strengthening phase are full knee ROM, quadriceps strength greater than 60% of non-surgical side, and normal gait pattern.^{29,30}

Full knee ROM should be achieved during this phase. Consultation of the surgeon may be necessary to prevent the development of complications, including arthrofibrosis.⁴⁴ While both open-chain and closed-chain exercises are both effective to improve quadriceps strength,⁴⁵ clinicians should consider the compression force at the patellofemoral joint when selecting exercises. Closed-chain exercises should be closely monitored to prevent femoral internal rotation coupled with dynamic knee valgus,⁴⁶ which can place abnormal loads on the healing graft. Maintaining proper lower extremity alignment and symmetrical loading of the surgical and non-surgical limbs should be emphasized during all exercises. Quadriceps strength testing using a hand-held dynamometer or isokinetic dynamometer should be initiated during this phase and throughout the course of rehabilitation to identify strength deficits and modify rehabilitation protocols accordingly. Return to running may commence when the following criteria has been met: full ROM or >95% of the non-injured knee, no pain or pain <2/10 on visual analogue scale and isometric quadriceps strength with limb symmetry index >70% (calculated by dividing the surgical side score by the non-surgical side score).⁴⁷

Balance/proprioceptive training is increasingly integrated into clinical practice for knee rehabilitation, and it has been shown to improve dynamic joint and postural stability.^{48,49} Exercises including wobble boards, ball tosses and balance cushions can be incorporated during rehabilitation. Single-legged balance exercises with the inclusion of perturbations can also be incorporated into rehabilitation to reinforce multi-planar control if satisfactory proximal limb control has been achieved. The application of perturbations or distractions can help challenge single leg stability required for the advanced strengthening and functional phase.⁵⁰

Table 1. Phases of Rehabilitation

Phase	Protection phase	Strengthening phase	Advanced strengthening and functional phase	RTS phase
Time period	0 to 6 weeks	6-12 weeks	12-16 weeks	>16 weeks
Milestones	• Knee flexion greater than 110° • Full knee extension • Straight leg raise without extension lag • Walking without crutches	• Full knee ROM • Quadriceps strength greater than 60% of the non-surgical side • Normal gait pattern	• Quadriceps strength greater than 80% of the non-surgical side • Hop tests greater than 80% of the non-surgical side	• Quadriceps strength greater than 90% of the non-surgical side • Hop tests greater than 90% of the non-surgical side • Composite score on the Y-Balance test greater than 90%
Interventions	• Heel slides, supine wall slides, heel propping/prone hangs • Quadriceps sets, 3-way straight leg raises • Knee extensor/flexor: isometric/concentric (limited by ROM/weight-bearing precautions) • Conditioning: upper body ergometer/assault bike • UE resistance exercises in sitting positions or un-weighted positions	• Progressive lower body exercises per patient tolerance with target RPE in 6-8/10 • Begin balance and proprioceptive exercises • Single leg strengthening can begin and should be assessed critically as compensation can occur • Conditioning: continue upper body ergometer/assault bike • May begin cycling with moderate/high resistance, rowing ergometer, or incline walking on treadmill • May begin return to running if the following criteria are met: full ROM or >95% of the non-injured knee, no pain or pain <2/10 on visual analogue scale and limb symmetry index of quadriceps >70%	• Continue lower body strengthening exercises: leg press, squat/deadlift, lunge variations, step-up/down, heel taps, split squat. • Consider incorporation of power-based training activities to promote rate of force development: kettlebell swings, hang cleans, medicine ball slams • Progress balance and proprioceptive exercises, consider incorporation of dual task training modalities or neurocognitive elements during training • Initiate agility tasks with basic change of direction drills • Initiate plyometrics training: double-leg box jumps, double-leg squat jumps, bound and stick	• Progress agility tasks including multi-task and reactive based drills • Progress plyometrics to emphasize single-leg and explosive types of activities • Incorporate sports-specific drills that initiate pivoting/cutting and gradually return to sport-specific activities

THE ADVANCED STRENGTHENING AND FUNCTIONAL PHASE

The advanced strengthening and functional phase (week 12–16 post-surgery) should focus on continued restoration of knee muscle strength. The milestones of the advanced strengthening and functional phase are quadriceps strength greater than 80% of the non-surgical side and hop tests greater than 80% of the non-surgical side.⁴¹

Advanced strengthening should include targeted development of lower extremity power-based skills in anticipation of progressing into plyometric, change of direction, and agility tasks in the RTS phase. Compound movements, such as squats, deadlifts, cleans, with high loads greater than 80% 1RM may be indicated with appropriate adjustments in set and repetition schemes.⁵¹ Lower loads could be integrated with unilateral lower extremity training to elicit side specific adaptations in strength as well as initiate focused effort on rate of force development with a variety of tasks. Eccentric exercises should be incorporated into rehabilitation as eccentric strengthening is beneficial in increasing force production⁵² and is needed to decelerate and stabilize the knee joint during change of direction tasks. Exercise selection should foster strength gains aiming for bilateral limb symmetry and design individually based on multiple factors including the patient's goals, training history, and access to equipment.

Agility and plyometric activities should be initiated during this phase. Currently, no evidence-based guidelines exist for initiating plyometric exercises in rehabilitation settings after MPFL reconstruction. However, research suggests that progression to plyometrics should be based on strength and functional criteria, including a $\leq 20\%$ strength and endurance deficit between limbs, the ability to maintain a 30-second single-leg stance with eyes open and closed, and the absence of pain while demonstrating proper movement patterns (balance and proper alignment) during single-leg half squats, free weight squats, and lower-level plyometric drills.⁵³ Agility drills involve dynamic and sport-specific movements that allow patients to adjust to sport-specific activities, such as accelerating and decelerating.⁵⁴ Plyometric training involves ballistic exercises and explosive movements that allow patients to improve neuromuscular control and enhance performance in competitive sports.⁵⁵ Beginner-level drills prioritize neuromuscular control and proper landing techniques. Initial tasks include ladder drills (e.g., in-and-out footwork) to improve coordination, cone drills (e.g., T-drills, lateral shuffles) for basic directional changes, and double-leg box jumps and pogo hops to emphasize knee alignment and controlled landings, minimizing dynamic knee valgus. As patients progress, exercises like 4-cone square drills, figure-8 runs, directional box drops/jumps, and lateral skater jumps help enhance dynamic stability and force production. In the advanced phase, complex agility drills and high-intensity plyometrics replicate sport-specific challenges. Movements like zig-zag cuts, pivoting maneuvers, depth jumps, single-leg lateral hops, and bounding help to develop multi-directional, sharp cutting abilities and explosive power. Proper landing mechanics, avoiding dynamic knee valgus, and monitoring

fatigue are key considerations for both injury prevention and optimizing performance. Progression of agility and plyometric activities can include advancing from bilateral to unilateral or linear to multi-directional exercises. The rate of speed or power can also be factors that help design the exercises appropriately. Hop tests are a performance-based measure that assesses dynamic knee stability during highly demanding activities⁵⁶ and can be initiated to track rehabilitation progression if the patient demonstrates sufficient neuromuscular control.

THE RTS PHASE

The RTS phase (>20 weeks) should focus on advanced plyometrics, cutting, accelerating/deceleration training and incorporate sport-specific movements. The milestones of the RTS phase are quadriceps strength greater than 90% of non-surgical side, hop tests greater than 90% of non-surgical side, composite score on the Y-Balance Test greater than 90%.²³

The training during this phase should be tailored to the demands of the patient's sport(s). Monitoring the number of foot contacts within an exercise session can be a safe way to progress plyometric exercises. For example, 80–100 foot contacts per session is ideal for a novice patient whereas 120–140 foot contacts per session would be more appropriate for an advanced patient.⁵⁷ Incorporate neurocognitive elements to exercises has been employed in RTS phase for performance enhancement and future injury prevention.^{58,59} Neurocognitive elements are designed to integrate cognitive challenges with physical movements, simulating the complex and unpredictable demands patients encounter during sports participation. For example, a dual-task exercise might involve performing a single-leg hop while simultaneously answering math questions or recalling a sequence of numbers. A reactionary drill could involve mirroring the physical therapist's movements, prompting quick, unplanned changes in direction. An interference task might include performing an agility ladder drill while the physical therapist calls out random directions or numbers, requiring the patient to adjust movements based on verbal cues. Inclusion of multi-plane, reactive and multi-task drills can assist in simulating competitive play and challenging neuromuscular control required for successful RTS. Clinicians can provide real-time cues to maintain proper lower limb alignment during drills. It is recommended to possess good movement quality under sport-specific situations such as change of direction at an obstacle. If applicable, a patient can begin with lower-level and non-contact practice followed by full-contact practice and gradually build up to competition, while monitoring any pain/instability.⁶⁰ While assessing readiness to RTS, patient-reported outcomes such as The Kujala Anterior Knee Pain Scale, The International Knee Documentation Committee (IKDC) Subjective Evaluation Form and The Knee Injury and Osteoarthritis Outcome Score (KOOS), should be considered to help with decision making.

BIOMECHANICAL CHARACTERISTICS DURING FUNCTIONAL TASKS

Few studies have examined biomechanical characteristics after MPFL reconstruction. During a fatiguing step down task, individuals at 15 months after MPFL reconstruction showed lower levels of vastus medialis obliquus and gluteus medius muscle activation compared to uninjured controls.⁶¹ During the stance phase of walking, individuals at three months after MPFL reconstruction demonstrated decreased knee flexion angle and knee extension moment on the surgical leg compared to uninjured controls.^{62,63} Knee flexion angle and knee extension moment on the surgical leg improve at one year after MPFL reconstruction and become comparable to uninjured controls,^{62,63} which suggests that altered walking biomechanics is not restored until one year after surgery. During landing in a drop vertical jump task, individuals who have been cleared to RTS (tested at 6-19 months after surgery) exhibited reduced knee flexion and ankle dorsiflexion angle, as well as decreased knee extension moment compared to uninjured controls.⁶⁴ In a single-legged drop landing task, individuals who have been cleared to RTS continued to exhibit reduced ankle dorsiflexion angle and decreased knee and ankle extension moments compared to uninjured controls.⁶⁴ Despite medical clearance to RTS, individuals after MPFL reconstruction may continue to exhibit biomechanical deficits in high-demanding physical activities. While current studies predominantly focus on sagittal plane biomechanics, future research should investigate frontal and transverse plane abnormalities, such as hip internal rotation and adduction, to identify faulty patterns that may predispose patients to recurrent patellar instability after MPFL reconstruction.

PATIENT-REPORTED OUTCOMES

Patient-reported outcomes are a subjective measure that allows clinicians to quantify the status of a patient's health condition from the patient's perspective and effectively track the improvements in the subjective outcomes during rehabilitation. Serial assessments of patient-reported outcome instruments can help monitor pain, function, and knee-related quality of life throughout various rehabilitation stages. Additionally, administering patient-reported outcome instruments at different phases can identify patients with persistent pain or functional limitations, facilitating timely interventions and personalized adjustments needed in their rehabilitation. Several patient-reported outcome instruments are available to use in MPFL reconstruction and patellar instability populations (Table 2). The Kujala Anterior Knee Pain Scale evaluates subjective symptoms and functional limitations in patellofemoral disorders,⁶⁵ and is recommended to use when taking a standardized clinical history of a patient. In pediatric patients, the mean Kujala score has been shown to improve from 61% pre-operatively to 81% at one-year follow-up and 90.7% at three-year follow-up.^{66,67} In adult patients, the mean of Kujala score improved from 56.1%-75.5% pre-operatively to 80% at one-year follow-up, 76%-88.3% at three-year follow-up and 88.8% at six-year follow-up.⁶⁷⁻⁷¹ The Banff

Patella Instability Instrument (BPII) and its revised version BPII 2.0 is specifically developed for patients with patellofemoral instability to evaluate symptoms/physical complaints, work-related concerns, recreational activity and sport participation/competition, lifestyle, and social/emotional status.⁷²⁻⁷⁴ In adult patients, the mean BPII score improved from 26.1 points pre-operatively to 64.9 points at one-year post-operatively and up to 68.7 points at two-years post-operatively.^{75,76} The mean BPII 2.0 score improved from 26.1-46.5 points pre-operatively to 66.1 points at one-year post-operatively, 71.8 points at two-years post-operatively and 80.4 points at three-years post-operatively.⁷⁷⁻⁷⁹ The Norwich Patellar Instability (NPI) is also specifically developed for patients with patellofemoral instability to evaluate their perceived patellar instability to activities that may produce patellofemoral instability.⁸⁰ In adult patients, the mean NPI score improved from 33.3-40.1 points pre-operatively to 29.3 points at one-year post-operatively and 3.7 points at three-years post-operatively.^{81,82}

IKDC evaluates symptoms, physical activity and function for patients with a variety of knee disorders, including patellofemoral dysfunction.⁸³⁻⁸⁵ The Pediatric IKDC Subjective Evaluation Form (Pedi-IKDC) was developed for children and adolescents (aged 10-18 years) to evaluate symptoms, function, and sports activity.⁸⁶ In pediatric patients, the mean IKDC score at one-year post-operatively was reported at 89.1%.⁶⁴ In adult patients, the mean IKDC score was reported at 42.1%-55.5% pre-operatively, 50.1% at six-weeks post-operatively, 56.6% at three-months post-operatively, 75% at six-months post-operatively, 77%-85% at one-year post-operatively, 80.2%-86% at two to approximately two and a half years post-operatively.⁸⁷⁻⁹³ KOOS and The Knee Injury and Osteoarthritis Outcome Score for Children (KOOS-Child) evaluates pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life for patients with an acute knee injury and early osteoarthritis.^{94,95} The KOOS is recommended for ages 16 and older while the KOOS-Child is used for children ages 7-16.⁹⁶ In pediatric patients at minimum six months after MPFL reconstruction, the mean KOOS subscale score has been reported as follows: ADL 95.52, Pain 89.02, Sports 73.64, Symptoms 80.64 and QoL 61.94.⁹⁷ In adult patients, the mean KOOS subscale scores pre-operatively and five-years post-operatively has been reported as follow: ADL 82.5 to 96.3, Pain 71.9 to 93.2, Sports 51.4 to 82.9, Symptoms 70.7 to 88.5 and QoL 45.5 to 80.7.⁹⁸ Clinicians should be aware of the differences between each of these PRO measures in order to determine which score is most relevant and practical to implement into daily clinical practice.

IMPAIRMENT-BASED OUTCOMES

Quadriceps strength deficit is a commonly reported impairment after MPFL reconstruction and can present long term.⁹⁹ An improvement in isometric knee extensor strength has been shown from pre-surgery to six weeks post-surgery.⁹² However, up to 20% deficits in isometric and isokinetic knee extensor strength have been shown in

Table 2. Overview of patient-reported outcomes

Questionnaire	Key elements	Score	Minimal detectable change	Minimal Clinically important difference
Kujala Anterior Knee Pain Scale	Symptoms Functional limitations	0 to 100 Higher scores indicate less pain and disability	13	9.1
Banff Patella Instability Instrument (BP II) and its revised version BP II 2.0	Symptoms/physical complaints Work-related concerns Recreational activity and sport participation/competition Lifestyle Social/emotional	0 to 100 Higher scores indicate better quality of life	6.2 (BP II 2.0)	6.2 (BP II 2.0)
Norwich Patellar Instability (NPI)	Patient-reported activities associated with instability	0 to 100 Higher scores indicate more perceived instability	Not reported	Not reported
International Knee Documentation Committee (IKDC) Subjective Evaluation Form and Pediatric IKDC Subjective Evaluation Form (Pedi-IKDC)	Symptoms Physical and sports activities Function	0 to 100 Higher scores indicate higher level of function	Not reported	9.9 (IKDC)
Knee Injury and Osteoarthritis Outcome Score (KOOS) and Knee Injury and Osteoarthritis Outcome Score for Children (KOOS-Child)	Pain Symptoms Activities of Daily Living (ADL) Sport and recreation function Knee-related quality of life	0 to 100 Higher scores indicate less knee problems	Not reported	9.0 (KOOS-Pain) 10.8 (KOOS-Symptoms) 10.0 (KOOS-Activities of Daily Living) 17.8 (KOOS-Sports and Recreation) 12.7 (KOOS-Quality of Life)
Pain Catastrophizing Scale (PCS)	Rumination Magnification Helplessness	0 to 52 Higher scores indicate higher level of catastrophizing	Not reported	Not reported

the surgical leg compared to non-surgical leg and normative data at six months to five years after surgery.^{23,99-102} These research studies indicate that quadriceps strength deficits can persist after being cleared to full participation in sports.

Hamstring strength is also frequently assessed after MPFL reconstruction. At 6-7 months after surgery, 5-17% deficits in isometric and isokinetic knee flexor strength are observed in the surgical leg compared to non-surgical leg.^{23,101} At one year after surgery, isokinetic knee flexor strength has been shown to be 90.7% of the non-surgical leg and no significant difference was observed between the patients with MPFL reconstruction and their age, gender and activity level-matched controls.⁶⁴ The recovery in isokinetic knee flexor strength continues and improves to less than 5% deficits at five years after surgery.¹⁰² For hip muscle strength, only one study has assessed isokinetic hip abductor strength at one year after surgery and showed above 100% symmetry and no significant differences when compared with age, gender and activity level-matched controls.⁶⁴

Poor knee joint proprioception is another potential impairment after MPFL reconstruction. Joint position sense did not significantly change from pre-surgery to six weeks post-surgery and to one year post-surgery,⁹² which indicates that joint position sense may not be considerably altered during the first year after MPFL reconstruction in the young adult population.

PERFORMANCE-BASED OUTCOMES

Hop tests have been traditionally used as a performance outcome in populations who have undergone knee surgery. These tests provide objective measures to assess rehabilitation progression and readiness to RTS in clinical settings. Although hop tests are primarily validated in patients with ACL reconstruction,¹⁰³ they have been used in patients with recurrent patellar dislocation to evaluate asymmetries that may predispose patients to patellar instability,¹⁰⁴ and to assess functional performance in patients with MPFL reconstruction.¹⁰⁵ Four different single-legged hop tests, including single hop for distance, triple hop for distance, triple crossover hop for distance, and 6-meter timed hop (Table 3), have been recommended to use starting at 12-19 weeks after MPFL reconstruction.³¹ At seven months to four years after surgery, limb symmetry index of single hop for distance has been reported between 89.7% to 97%.^{23,64,106} Limb symmetry index of triple hop for distance and triple crossover hop for distance has been reported between 92.3% to 99% and between 92.5% to 98.1%, respectively.^{23,64,106} Limb symmetry index of 6-meter timed hop has been reported between 95.8% to 98%.^{23,106} Compared to age and sex-matched controls, patients at one year after MPFL reconstruction took significantly longer to complete the 6-m timed hop test (MPFL reconstruction: 2.93 seconds, controls: 2.51 seconds).

The lower quarter Y-Balance test (YBT-LQ), square jump and step down test have also been used in patients after MPFL reconstruction (Table 3). YBT-LQ is a widely accepted tool for assessing dynamic balance and neuromuscular con-

trol deficits commonly observed in patients with MPFL reconstruction.¹⁰⁵ At seven months after surgery, the mean difference between limbs in anterior reach on the YBT-LQ was 3.5 cm with a composite score of the surgical limb at 94.9% of leg length.²³ Compared to uninjured controls, patients at 45 months after MPFL reconstruction completed 11.5 sets versus 21 sets in the square jump and 11.5 sets versus 22 sets in the step-down test.¹⁰⁷ The side hop test, lateral step-down test and lateral leap and catch are additional tests that can be used to assess the quality of functional tasks.⁴¹

PSYCHOLOGICAL MEASURES

Poor psychological readiness is reported as one of the reasons for not returning to sports following MPFL reconstruction.⁸ Several self-report questionnaires are available to quantify psychological distress. The Pain Catastrophizing Scale (PCS),¹⁰⁸ Tampa Scale for Kinesiophobia (TSK) and its shortened version (TSK-11), Fear-Avoidance Beliefs Questionnaire (FABQ) have been used to measure psychological factors (pain catastrophizing and fear of re-injury) in the fear-avoidance model (Table 4). Previous literature on psychological distress in patients with MPFL reconstruction has been limited. For pain catastrophizing, a mean score of 18.9 ± 16.7 points on PCS was reported pre-operatively and decreased to 15.7 ± 15.4 points at one-year post-operatively.¹⁰⁹ For fear of re-injury, a mean score of 32.4 ± 5.0 points on TSK was reported at one-year post-operatively.⁶⁴ Another questionnaire that has items related to fear of re-injury during sport activities is the MPFL-Return to Sport after Injury (MPFL-RSI). A MPFL-RSI score > 56 points indicates a patient is psychologically ready to return to play.⁸ Previous research identified mean scores of 44.2 ± 21.8 points and 60 ± 27 points at approximately three-year and four years post-operatively, respectively.^{8,110}

Self-efficacy, or confidence, is another psychological factor that is related to rehabilitation outcomes after knee surgery/injury (Table 4).¹¹¹⁻¹¹³ Questionnaires that can be used to measure self-efficacy are the Self-Efficacy for Rehabilitation Outcomes Scale (SER),¹¹⁴ Knee Self-Efficacy Scale (K-SES)¹¹⁵ and Knee Activity Self-Efficacy (KASE).¹¹⁶ Although self-efficacy or level of confidence has not been investigated in the MPFL reconstruction population, research studies have reported lack of confidence as one of the reasons for not returning to play and/or reduced activity level following MPFL reconstruction.^{8,117} Therefore, it may be beneficial to measure psychological distress when a patient begins advanced rehabilitation or include it as part of a battery of tests for RTS clearance.

RTS RATE AND CRITERIA

The average time to RTS is reported at 7-8 months after surgery.^{118,119} Successful RTS rates following MPFL reconstruction have been reported at 53%-91%^{91,118-121} with 53%-68% of patients returning to the same or higher level of participation prior to their injury. When establishing RTS criteria following MPFL reconstruction, a multifactorial approach that includes time-based criteria, subjective and ob-

Table 3. Overview of performance-based outcomes

Test	Task	Outcome measure
Single leg hop tests	Single hop for distance: hops as far as possible on one leg	Maximum distance
	Triple hop for distance: hop three consecutive times on the same leg, covering as much distance as possible	Total distance
	Triple crossover hop for distance: hop three consecutive times laterally (side-to-side) on the same leg, covering as much distance as possible	Total distance
	6-meter timed hop: hop forward on the same leg for the full 6-meter distance, covering the ground as quickly as possible	Total time
Lower Quarter Y-Balance test	Stand on one leg at the center of the Y grid and reach as far as possible with the opposite leg along each of the three lines (anterior, posterolateral, and posteromedial) while maintaining balance	Composite score: the sum of 3 reach directions divided by 3 times the leg length then multiplied by 100
Square jump	Stand outside a 30x35 cm square and jump clockwise in and out for 30 seconds	Number of times the foot touches inside the square without touching the tape
Step down	Step forward and down from an 8-inch platform, allowing the heel of the down limb to touch the floor, then return to full knee extension	Number of repetitions performed in 30 seconds
Side hop	Hop on one leg between two lines 40 cm apart in 30 seconds	Number of repetitions performed in 30 seconds Quality of change in direction and endurance are also evaluated
Lateral step-down	Stand on one leg at the edge of a box, step down laterally to 60° knee flexion, tap the contralateral heel to the ground, and match an 80 bpm cadence for 3 minutes	Loss of balance, significant trunk lean or knee valgus, and inability to match the beat of the metronome are evaluated
Lateral leap & catch	Hop laterally from one leg to the other at 60% of the height, following a 40 bpm cadence for 60 seconds	Quality of the motion and the agility to match the beat of the metronome are evaluated

Table 4. Overview of psychological measures

Tampa Scale of Kinesiophobia (TSK) and its shortened version (TSK-11)	Activity avoidance Somatic focus	17 to 68 Higher scores indicate greater level of kinesiophobia	Not reported	Not reported
Fear-Avoidance Beliefs Questionnaire (FABQ)	Physical activity Work activity	0 to 96 Higher scores indicate higher fear-avoidance beliefs	Not reported	Not reported
MPFL-Return to Sport after Injury (MPFL-RSI)	Psychological readiness to RTS	0 to 100 Higher scores indicate greater psychological readiness and confidence to RTS	Not reported	Not reported
Self-Efficacy for Rehabilitation Outcomes Scale (SER)	Belief about the ability to perform behaviours typical of physical rehabilitation	0 to 120 Higher scores indicate higher level of self-efficacy	Not reported	Not reported
Knee Self-Efficacy Scale (K-SES)	Daily activities Sports and leisure activities Physical activities Future knee function	0-180 (present) 0-40 (future) Higher scores indicate higher level of self-efficacy	Not reported	Not reported
Knee Activity Self-Efficacy (KASE)	Confidence in performing functional activities	0-100 Higher scores indicate greater self-efficacy in knee-related activity	Not reported	Not reported

jective criteria should be considered. Current literature related to RTS criteria following MPFL reconstruction mostly use time-based criteria (66%) while only 10% of research studies use subjective or objective criteria to determine RTS readiness.¹²²

RTS criteria following MPFL reconstruction have not been well established. The RTS testing after MPFL reconstruction typically utilizes similar criteria as in the ACL reconstruction, including limb symmetry index $\geq 90\%$ on single-legged hop tests (single hop for distance, triple hop for

distance, triple crossover hop for distance and timed hop), a composite score of $\geq 90\%$ on each limb and side-to-side difference of $< 4\text{cm}$ on the anterior reach of the Y-Balance Test and limb symmetry index $\geq 90\%$ on isometric peak torque for knee extension, knee flexion, and hip abduction.^{23,123}

SUMMARY

MPFL reconstruction is a reliable treatment for recurrent patellar dislocation. While no validated rehabilitation protocols are established following MPFL reconstruction, recommendations for rehabilitation guidelines can be made for each phase. To protect the graft, initial knee bracing with gradual progression to full weight-bearing is required during the protection phase. Restoration of full knee ROM and weight-bearing should be achieved at six weeks following the surgery. When progressing to the strengthening phase, exercises should incorporate multi-joint movements in both open and closed chain with consideration of the compression force at the patellofemoral joint when selecting exercises. Objective knee strength assessment and functional tests, including single-legged hop tests, should be initiated during the advanced strengthening and functional phase. Majority of patients with MPFL reconstruction can return to the same or higher level of participation prior to their injury. When determining RTS readiness, a multifactorial approach that includes time-based, subjective, and objective criteria should be considered. Clinicians should utilize patient-reported outcomes and psychological measures to assess patients' perceived knee function and

psychological readiness to RTS. Limb symmetry in knee strength, single-legged hop tests, and the Y-Balance Test should also be included for RTS decision-making. Future research can fill knowledge gaps by investigating biomechanical characteristics during functional and sport tasks as well as identifying biomechanical deficits that should be addressed in rehabilitation that allow for safe RTS postoperatively.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest

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