Multiligament knee injuries in athletes, is it possible to return to play? —a rehabilitation perspective

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Abstract: Multiligament knee injuries (MLKI) are complex injuries with an array of factors that can impede return to play (RTP). Careful consideration of these factors in conjunction with periodized rehabilitation programming is strongly recommended to optimize patient outcomes after MLKI. This paper explores RTP rates, the factors that inhibit RTP, and provides an outline for designing a rehabilitation program for returning patients to activity.

Keywords: Rehabilitation; multiligament; knee; physical therapy; return to sport

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Introduction

Multiligament knee injury (MLKI) is a catchall phrase used to describe a spectrum of ligamentous knee injuries ranging from injury of two ligaments to disruption of all four ligaments. While rare relative to other injuries in the knee, MLKI can be devastating and impact other structures of the knee including the neurovascular, menisci, chondral, tendon, and capsular structures that may further complicate a care plan (1).

While controversy still exists regarding optimal surgical management, the evolution of anatomical ligament reconstruction of these injuries has resulted in improved restoration of joint stability and patient satisfaction (2). These results have naturally led to greater expectations for what level of activity can be achieved after MLKI, and they are both reasonable and possible. For the rehabilitation professional, this increased expectation surrounding outcomes has forced a critical evaluation of postoperative restrictions that are used to protect the surgical reconstructions as well as the methods employed to restore preinjury levels of strength and function. For the above mentioned reasons, the purpose of this paper is twofold: to understand the factors that limit return to play (RTP) in MLKI patients, and to outline a rehabilitation program and functional assessment that maximizes a patient's chance for RTP while guiding the decision making process for clinicians.

RTP rates

MLKI are complex with many variables involved in outcome statistics. As a result, RTP rates vary. Everhart *et al.* performed a systematic review investigating return to work or sport rates after MLKI. RTP rate at any level of sport was 59.1% for surgically managed MLKI (3). Return to a similar level of sport was much lower, with reported rates of 22% for competitive athletes and 33% for elite athletes (3). One study looking exclusively at 50 NFL athletes after MLKI reported a 64% RTP rate (4). Return to preinjury level of sport rates were lower, with only 30% of the NFL athletes achieving preinjury status (4). While possible to RTP, these statistics demonstrate the difficulty of returning to a high level of activity.

Factors limiting RTP

The complexity of MLKI makes it difficult to understand the extent to which individual factors affect a patient's ability to RTP. Concrete cause and effect conclusions of how one factor amongst the large number of variables may impact RTP cannot be drawn. Therefore, the goal is to review what other studies have identified as barriers and provide clinical commentary to assist medical providers in returning patients to athletic performance.

In general, more severe injuries tend to have worse outcomes, especially when both cruciates are involved (3,5). Mechanisms of injury that create MLKI may involve high velocities that inflict extensive injuries beyond the knee. These are classified as poly-traumatic MLKI. Woodmass *et al.* compared outcomes between MLKI and poly-traumatic MLKI. Patients with poly-traumatic injuries reported lower functional scores, and it was concluded that the knee is not the limiting factor to returning to prior level of function in poly-traumatic MLKI (5). In non-poly-traumatic cases, results are more mixed and necessitate consideration of ligaments involved, neurovascular injury, joint fracture, cartilage injury, and meniscal injury. After injury is considered, the impact of arthrofibrosis, ligament laxity, and muscle weakness must be evaluated as factors inhibiting RTP.

Specific ligaments involved

Everhart *et al.* performed a systematic review investigating return to work or sport after MLKI (3) They found that studies including patients with Schenck types IV and V injuries (6) reported lower return to work rates compared to studies without grade IV and V (3). Bakshi *et al.* studied RTP rates of NFL players after MLKI. Overall, they found that ligament injury pattern significantly affects RTP ($P=0.047$) (4). There was a 68.2% next-season RTP rate for athletes with ACL/MCL injury compared to 37% for athletes with combined ACL/PCL/FCL injury (4). Further, a higher percentage of players with ACL/MCL injury (43.5%) returned to preinjury level of function compared to players with ACL/PCL/FCL injury (18.5%) ($P<0.001$) (4). Explanations provided by the authors for these differences include different mechanisms of injury, different forces contributing to other concomitant injuries, and the non-operative healing potential of MCL injuries.

Neurovascular injury

Both neuro and vascular injuries can occur with MLKI. In these injuries, the common fibular nerve (CFN) and the popliteal artery are often the structures affected. Although the CFN may be damaged with variations of MLKI, Moatshe *et al.* found that CFN injury is 42 times more likely to occur when the PLC is injured compared to no PLC involvement (6). Also, the popliteal artery is nine times more likely to be injured when the PLC is involved in the MLKI (6). It is worth noting that MLKI involving severe intra-articular fractures were not included in this study (6).

The severity of fibular nerve palsy impacts recovery of muscle function (7). Full recovery (Medical Research Council score =5/5) was identified in 87.3% of patients with partial CFN palsy versus only 38.4% of patients with complete CFN palsy achieving functional recovery (MRC ≥3/5) (7). Krych *et al.* investigated whether or not fibular nerve injury leads to worse function after MLKI. When confounding variables were controlled for, no difference in Lysholm or IKDC scores were identified for those with and without fibular nerve injury (8). Unfortunately, functional testing (i.e., hop testing) and rates of RTP were not specified. Therefore, it cannot be concluded how fibular nerve injury affects what level of sport patients reach.

Even with these statistics, it is challenging to predict to what extent and on what timeline nerve function will be restored. Peskun *et al.* retrospectively reviewed 91 patients with MLKI, 26 of whom had fibular nerve injury (defined by lack of dorsal foot sensation and 0/5 MRC score) (8). The only variable associated with fibular nerve recovery was younger age (9). Incomplete nerve palsy may resolve without surgical intervention (7-9). For complete nerve palsy, surgical intervention is often necessary (10). Unfortunately, nerve grafting generally has poor results due to the fact that up to 15 cm of the nerve may be affected (11). Larger, more severe injuries requiring longer lengths of nerve grafting tend to have worse results (12). When nerve grafting is not a suitable option, or the grafting fails, posterior tibialis tendon transfer may be used to restore dorsiflexion function (10). However, studies measuring dorsiflexion strength after posterior tibial tendon transfer have found an average dorsiflexion strength index of 30% (13) and 42% (14) compared to the uninvolved side. Although this is a considerable strength deficit, Molund *et al.* reported that four of the twelve patients available for evaluation after posterior tibial tendon transfer were able to return to high levels of activity in marathon running and downhill mountain biking (14). Others were able to return to recreational levels of activity in biking, cross country skiing, dancing, squash, and football (14).

Sanders *et al.* performed a retrospective matched-cohort analysis comparing function after MLKI in those with and without vascular injury (15). Patients with vascular injury reported significantly lower IKDC (59.7% *vs.* 83.8%, P=0.002) and Lysholm scores (62.5% *vs.* 86.4%, P=0.001) than those without vascular injury (15). Although the authors stated they did not completely understand why results were worse in the vascular injury group, explanations included: prolonged tissue ischemia, external fixation, fasciotomy procedures, increased surgical morbidity, vascular graft-related complications, and prolonged immobilization (15). Many of these factors could lead to thinking that range of motion (ROM) would be negatively affected, but no differences in postoperative ROM were identified (15).

Articular cartilage and meniscal injury

Articular cartilage lesions may complicate recovery in MLKI, but to the authors' knowledge, no study has specifically investigated how the combination of MLKI and cartilage lesions impacts RTP. The best information available is a study by Schmitt *et al.* who performed a systematic literature review of functional outcomes after surgical management of articular cartilage knee injuries (16). To summarize the findings, deficits in functional performance may persist for five to seven years following articular cartilage surgical procedures (16). Although the population studied wasn't a MLKI population, it provides a clear view of how cartilage injury impacts recovery, and it may provide insight as to how cartilage injury impacts recovery after MLKI.

One reason cartilage injury and surgical intervention could complicate MLKI recovery is that rehabilitation timelines for cartilage procedures are often slow in order to allow protection of healing tissue. Delayed WB postpones all subsequent phases of rehab and ultimately leads to a longer rehabilitation. Strength training must be delayed, and the potential effects of this are observed with some strength impairments persisting up to two to seven years after articular cartilage repair (16). More progressive WB protocols that allow full weight bearing (FWB) at six weeks versus eight weeks after surgery may restore strength sooner after autologous chondrocyte implantation (17). How rapidly WB can be progressed without negatively impacting healing integrity is unclear. Further, important gait impairments persist regardless of progressive versus conservative rehabilitation (16). Sagittal plane knee kinematics and kinetics during gait are identified up to 12 months after surgery (16).

Meniscus tears are another intra-articular factor that impact rehabilitation and RTP. That being said, Jenkins *et al.* found no correlation between the presence of or lack of a meniscus tear and IKDC or SMFA scores (18). While some meniscus tears may have very little impact on WB timeframes and ROM progressions, repairs stressed by hoop tension, such as meniscal root tears, require protection timeframes for both ROM and WB. Meniscal root tears have a reported occurrence of 20.2% in MLKI cases (19).

Arthrofibrosis

There are varying grades of arthrofibrosis (20), but all impact patient function. With a loss of knee extension alone, basic gait pattern is disrupted and cannot be normalized due to physical block in terminal extension. Reported incidence of arthrofibrosis after MLKI varies (7,21,22). As mentioned earlier, it is not clear whether acute versus delayed management provides superior results (21,22). However, a retrospective case control study identified combined ACL/PCL/PLC injury (OR =17.08), knee dislocation (OR =12.84), and use of an external fixator (OR =12.81) as significant risk factors for stiffness (23).

Laxity

While stiffness after MLKI is a concern, laxity is also a concern. Great care is taken with anatomical reconstruction to restore as normal mechanics as possible. If laxity develops postoperatively, the overall integrity and function of the knee may be affected. Due to this concern, rehabilitation protocols err on the side of caution when determining initial WB status and appropriate progression. Precautions to protect ligament healing often extend up to four months and beyond, depending on the ligament reconstructed (*Table 1*). Most of these precautions have not been systematically compared to more progressive alternatives. Instead, they are based on anticipated physiological healing and tissue maturation timelines. However, one study did compare NWB for six weeks to partial weight bearing (PWB) at 40% of body weight with crutches for six weeks after isolated FCL reconstruction or ACL/FCL reconstruction (24). At

Table 1 Postoperative restrictions

Ligament reconstructed	ROM	WB status	Brace	Stationary bike	Miscellaneous
ACL	FROM	PWB ×2 weeks	Hinged knee brace	10 days	–
PCL	0–90×2 weeks then FROM. All prone	NWB ×6 weeks	PCL dynamic anterior draw brace ×24 weeks	6 weeks	No open kinetic chain hamstrings ×16 weeks
MCL	0–90×2 weeks then FROM	NWB ×6 weeks	Immobilizer ×6 weeks	6 weeks	–
FCL	0–90×2 weeks then FROM	PWB ×6 weeks	Immobilizer ×2 weeks then hinged knee brace	2 weeks	No open kinetic chain hamstrings ×16 weeks; avoid tibial external rotation ×4 months

ROM, range of motion; WB, weight bearing; ACL anterior cruciate ligament; PCL, posterior cruciate ligament; MCL, medial collateral ligament; FCL, fibular collateral ligament; PWB, partial weight bearing; NWB, non-weight bearing; FROM, full range of motion.

Table 2 Strength indices of quadriceps muscles at 6, 12, and 24 months (18)

Isokinetic strength: peak torque	6 months	12 months	24 months
Quadriceps (% of uninjured knee)	58.6 (50.1 to 67.1)	73.1 (62.4 to 83.8)	84.6 (77.3 to 91.8)

the six months follow up, no differences in laxity between the two groups were found (24) Further investigation is necessary to determine the effects of progressive WB on laxity and function for other ligamentous repairs.

Strength deficits

Many studies report IKDC and Lysholm scores after MLKI, but physical testing of strength and function (i.e., quadriceps index, hop test) are rarely discussed. To the authors' knowledge, there is only one study that reports strength indices (summarized in *Table 2* (18). The main takeaway is that strength deficits in the quadriceps persist at two years after surgery. This is comparable to several ACL studies that show it takes up to two years to resolve impairments in quadriceps and hamstrings strength after ACL reconstruction (25-28). This is of concern because patients are typically cleared prior to two years after surgery, and strength deficits are often observed after patients are cleared to RTP (29). Normalizing strength prior to RTP is an important issue to address due to the negative impact of residual weakness on function (30).

Rehabilitation recommendations

The rehabilitation plan and process following surgery for a MLKI is a key component of achieving a successful outcome and providing the opportunity for patients to return to their previous level of sporting activity. The variation of reconstructed structures makes for some differences in the specific rehabilitation protocols; however, the following principles are common to the acute management phase of post-surgical:

(I) Protect the surgical reconstruction and restore joint range of motion (ROM);
(II) Manage the scarring process;
(III) Minimize muscular atrophy and restore preinjury levels of muscular strength;
(IV) Utilize return to sport testing to guide decision making.

Protect the surgical reconstruction & restore joint ROM

Following early surgery, immediate ROM has been reported to reduce the incidence of flexion loss of >10° and extension loss >5° (22). This is significant since residual stiffness is the most common complication after a multiligament knee reconstruction (31). While there are numerous benefits of early mobility, there remains a large variation in the literature for timing of post-surgical ROM and the amplitude allowed (1). As a guideline for clinicians, PROM of 0–90° for two weeks and then full ROM thereafter has been reported as safe ROM restriction for all ligamentous injury patterns (24,32,33).

For the majority of injury patterns, patients are NWB for a period of six weeks (32,33). This is to limit WB load on the reconstructed ligaments and the resultant risk of graft elongation and joint laxity. An exception to this is patients with combined ACL/FCL reconstructions. In a randomized controlled trial, LaPrade and colleagues demonstrated there were no significant differences in pain, ROM, subjective outcome, stability, or swelling between the control NWB group and the experimental PWB group (24).

For PCL-based MLKI's it is recommended to utilize a dynamic brace for six months. This brace provides a dynamic anterior draw force to the proximal tibia, limiting posterior tibial sag and PCL stress with increased degrees of flexion. In a three year follow up cohort study of 100 PCL patients, the use of an anterior draw brace for six months combined with a double bundle anatomic reconstruction and early ROM that began day one post-surgery improved preoperative posterior tibial translation from 11.0±3.5 to 1.6±2.0 mm postoperatively (33). For ACL-based MLKI, patients are advised to utilize a knee immobilizer for a 6-week duration, with the patient needing to demonstrate a straight leg raise with less than a 5° quadriceps lag to open up the brace during WB 91). A list of postoperative restrictions is found in *Table 1*.

Manage the scarring process

The most frequent MLKI complication of joint stiffness is largely related to the development of scar tissue and subsequent arthrofibrosis. Scarring in the anterior knee is shown to result in the negative consequences of increased patellofemoral and tibiofemoral joint contact pressures, reduced moment arm of the extensor mechanisms, and a cause of anterior knee pain (34,35). While there is no single rehabilitation intervention to reduce the incidence of arthrofibrosis, a treatment plan that includes early ROM (day one postoperative), patellofemoral mobilization, and appropriate loading decisions that help resolve of joint effusion and inflammation is prudent. Mueller *et al.*, advocate manual postoperative patellofemoral mobilization as a means to mitigate the restriction of normal joint mechanics by scar tissue (36). This manual patellofemoral mobilization influences the entire anterior knee, with a specific focus on maintaining the integrity of the anterior interval and suprapatellar pouch.

Minimize muscular atrophy

Given that significant strength deficits have been reported following surgery for MLKI, special attention and effort should be given reducing muscular atrophy. The use of blood flow restriction training (BFR) shows promise in this area. BFR involves the occlusion of venous return and the restriction of arterial inflow through the application of an extremity tourniquet. Muscle hypertrophy is promoted when completing exercise with the tourniquet inflated through a combination of processes including cell signaling, hormonal changes that stimulate protein synthesis, and proliferation of myogenic cells (37-39). While lacking the clinical trials to help elicit the optimal dosing, it has been suggested that the following protocol may be beneficial in resisting atrophy: initiate BFR treatment once proximal thigh sensation is normal, perform at a frequency of three to six days per week, utilize 80% limb occlusion pressure, and complete a set and repetition structure of 1×30, 3×15 with 30 seconds rest between sets for each muscle group of interest (40).

Restoration of muscular strength

With strength deficits persisting until 2 years post-surgery (18), the restoration of strength takes on particular significance in MLKI patients. One method of organizing the development of strength is through periodization. Periodization is the division of a training or rehabilitation program into smaller phases (periods) as a means of creating more manageable segments (41). Further, periodized programs increase specificity of training, are effective in creating gains in strength, and help avoid training plateaus (42). *Tables 3*, *4*, and *5* describe the parameters and sample treatments.

Return to sport testing

The importance of return to sport testing and its role in reducing reinjury risk is well described in the ACL literature (43,44). Despite this, little work exists in the MLKI rehabilitation literature surrounding the understanding of residual muscular strength and movement pattern deficits following MLKI surgery or the effectiveness of RTP testing. Since muscular strength deficiencies have

Table 3 Muscular endurance phase sample programming

Intervention examples:
Double leg leg press
Double leg bodyweight squat
Isometric lunge hold with trunk rotation
Monster walk
Tuck squat
Parameters:
3 sets, 12–15+ repetitions, 1 minute rest, 3 times per week
Goals/criteria to advance:
Quadriceps index >80%
Anterior reach on Y-Balance Test, <8 cm difference compared to uninvolved side

Table 4 Muscular strength phase sample programming

Intervention examples:
Single leg leg press
Single leg deadlift
Multi-directional lunges
High bench step ups
Hex bar squats
Parameters:
3 sets, 8–12 repetitions, 2–3 minutes rest periods between sets, 3 times per week
Goals/criteria to advance:
Quadriceps index >90%
Anterior reach on Y-Balance test, <4 cm difference compared to uninvolved side

Table 5 Muscular power phase sample programming

Parameters:
3–5 sets, 3–8 repetitions, 3 minutes rest periods between sets, 3 times per week
Goals/criteria to advance:
Single leg hop series <10% deficit for all tests
Knee abduction moment <8º on box drop assessment
Agility T-test or modified agility T-test <11 s

been demonstrated as far out as two years post-surgery (18) and reduced muscular strength and movement pattern deficiencies are related to knee injuries (43,45-47) it seems appropriate to follow a return to sport testing protocol similar to that used after ACL reconstruction. In addition to the cornerstone strength and power tests of RTP criterion, it is important that movement quality also be observed (48,49).

RTP assessment has been incorporated into the progression criteria for each periodized phase in the sample rehabilitation program outlined in this paper. Rehabilitation professionals can use these progression criteria as a means to assess patient progress, with the cumulative passing of each phase's assessment resulting in clearance to RTP. Alternatively, clinicians may use the criteria outlined with the power progression (*Table 5*) as the final RTP assessment.

Conclusions

While return to a competitive level of sports is very difficult after MLKI, it is possible for the athlete to overcome significant injury through surgery and rehabilitation. We advocate for future MLKI studies to structure rehabilitation into periodized progressions to optimize recovery. Finally, it is encouraged that all athletes recovering from MLKI undergo rigorous RTP testing to help ensure safety and success in returning to sport.

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Footnote

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