Review Article

High quality rehabilitation to optimize return to sport following lateral meniscus surgery in football players

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Abstract: There is a paucity of studies in the literature pertaining about how to guide rehabilitation and return to sport (RTS) progression for football players that have sustained a lateral meniscus injury and subsequent surgery. These patients are clinically challenging. If they return to sport too soon, before the rehabilitation process is completed and RTS criteria have been met, functional outcomes could be non-optimal and/or associated with higher reinjury risk. The aims of this paper are (I) to provide a brief overview of the current trends in acute lateral meniscus tears surgery in football players and (II) to suggest a framework for clinicians on how to progress the player following lateral meniscus surgery. Post-operative rehabilitation approaches are different for meniscus repair and for the other surgical techniques. The main goal of all involved practitioners should be to balance the "short term success" with the "long term protection" of the athlete's health. Specific key goals and interventions in early-, mid-, and late-stage rehabilitation are provided. The most important principle is to manage the progressive increase in loading through multiple measurements including frequent medical control consultations and functional tests detailing movement quantity and quality. RTS monitoring needs to be comprehensive and interdisciplinary, incorporating state of the art tests, to achieve recovery of sport-specific fitness, optimal movement quality and on-field rehabilitation progression.

Keywords: Lateral meniscus; meniscus surgery; rehabilitation; return to sport; football

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Introduction

Over the course of a century, between the late 1800s and late 1900s, the menisci went from being considered "functionless structures" (1) to "one of the most important structures of the knee" (2). This process took place thanks to the evolution of scientific research and innovation, particularly involving the discovery of the increased risk of joint degeneration associated with the loss of meniscus tissue (3). In the younger athlete meniscus tears occur at a rate of 5 per 100,000 athlete exposures (AEs) accounting for 10% to 20% of all knee injuries (4). A higher prevalence of medial versus lateral meniscal tears has been reported with the medial meniscus consistently 2 to 3 times more likely to be injured compared with the lateral meniscus (5,6).

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Meniscus injuries are frequently seen in young and physically active population (range, 18–39 years age) participating in American football, football, basketball, and wrestling (7,8). In high school athletes, it was found that females participating in football, basketball, softball, lacrosse, and track and field had more than two-fold risk of meniscus injury compared to males (4). Injury rate was higher in competition than in training. Player-to-player contact was reported as the most common injury mechanism (41.9% of all injuries), followed by non-contact (38.2%) with females having a higher proportion of injuries caused by non-contact mechanisms than males (4). A pivoting movement with a planted foot was the most common specific injury mechanism overall, and it was the most common mechanism in football, baseball and softball, while jumping and landing accounted for the majority of injuries in basketball and volleyball (4).

Menisci injuries are commonly associated with concomitant injuries of the knee: in high school athletes, 54% of reported meniscal injuries had at least one concomitant knee injury, and the most common associated injury was anterior cruciate ligament (ACL) tear (36.9%) (4). The incidence of ACL injuries with meniscus tears in young (mean age 25.4 years) athletes varies considerably, ranging from 16% to 82% in acute ACL injuries and up to 96% in chronic ACL insufficiency (9). Lateral meniscus tears are mainly found in acute ACL injuries, while medial meniscus tears are more common in patients with chronic ACL injuries (10).

According to the 2019 ESSKA meniscus consensus statements, in general, traumatic meniscus tears are treated with repair, left *in situ*, or partial meniscectomy (11).

Repair and partial meniscectomy are the most chosen treatment options, whereas left *in situ* is recommended for stable asymptomatic tears of the lateral meniscus during ACL reconstruction (ACLR) (12). Partial meniscectomy of traumatic meniscus tears should only be applied if the other two treatment options are not applicable, e.g., in complex tears, flap tears or nonreducible bucket handle tears. For acute root tears, treatment options include arthroscopic repair, meniscectomy or a non-surgical approach. In all three groups, improvement can be expected after 12 months. Based on available evidence, it has been suggested that arthroscopic repair may have a better protective role in terms of slowing down the onset of osteoarthritis (13). When repair is required, surgery should be performed as early as possible (11). In general, preserving as much as possible of the meniscus is important for long term health of the knee joint (12).

There is a paucity in the literature pertaining about how to guide rehabilitation and return to sport (RTS) progression for football players that have undergone lateral meniscus surgery.

RTS criteria should be based on a complete rehabilitation progression and on passing objective clinical tests and subjective functional assessment scores (14,15). If players return to sport too soon, before the rehabilitation process is completed and RTS criteria have been met, functional outcomes may be non-optimal.

To support decision making of RTS, clinical test for swelling/effusion [e.g., modified stroke test (16)], joint tenderness [e.g., joint line tenderness test (17)], and meniscus tests [e.g., McMurray's test and Apley's test (18) are used. In addition subjective scores [e.g., IKDC, KOOS, Tegner activity score are recommended (19)]. On the other hand, objective outcome measurements are rare in the literature. Moreover, comprehensive clinical milestones during rehabilitation are lacking. For example, Willinger *et al.* (19) investigated MRI signal alterations after acute meniscus repair and correlated it with clinical outcomes and RTS (12). Thirty patients with a total of 35 meniscus tears (19 medial, 16 lateral) were included. MRI examination six months after surgery revealed a continuous healing process and, at final follow-up, lateral menisci were classified as 62.5% healed, 31.3% partially healed and 6.2% non-healed, while medial menisci were classified as 50.0% healed, 38.9% partially healed and 11.1% non-healed. The RTS rate was 100% whereof 44.8% reached their pre-injury level. MRI examination six months after surgery revealed a continuous healing process and menisci were classified as 55.9% healed, 35.3% partially healed and 8.8% non-healed at final follow-up. In other words, based on MRI, healing was not completed yet they had already returned to sports (12).

This also brings forward questions. What are the criteria to RTS? Should these criteria be based on clinical and functional assessment like other knee injury domains such as the ACL? In the authors view a solid yes is the correct answer.

In sum, there is a paucity of studies in the literature pertaining about how to guide rehabilitation and RTS progression for football players that have sustained a lateral meniscus injury and subsequent surgery. Thus, the aim of this manuscript is to present a framework for clinicians on how to progress the player after lateral meniscus surgery.

Trends in lateral meniscus surgery and rehabilitation

In the last 20 years partial meniscectomy is decreasing, and

meniscal repair is increasing (20), in a general accepted philosophy to preserve as much as we can the meniscal tissue.

Meniscus allografts transplantation (MAT) should be treated separately as they are relatively rare procedures, mainly performed by expert surgeons. After MAT a long rehabilitation process is warranted and should be considered as a salvage procedures in football players (21,22), especially after previous lateral meniscectomies in older players.

Getting back to common procedures, post-operative rehabilitation differs for meniscus repair and partial meniscectomy (23). More generally, the main goal of the sports medicine practitioners should be to balance the "short term success" with the "long term protection" of the player's health. Indeed, most professional players are not aware that sporting injuries are occupational injuries requiring behaviors determined by occupational safety and health rules (24). Occupational risk communication should be improved by establishing a proactive injury prevention culture and identifying clear-cut responsibilities for key stakeholders within sport organizations. Athletes perceive an injury only when it hampers performance (25). Hence, in sports medicine, athletes should also be informed about the long-term health of the knee joint.

Arthroscopic partial meniscectomy and considerations for rehabilitation

Meniscectomy can involve partial, subtotal, or total removal of the damaged meniscal tissue and should be used only when a repair not feasible (26).

Although players are able to return to physical activities much faster following partial meniscectomy, the risk of early degenerative changes must not be underestimated (8).

Recently, as mentioned above, it has been recommended to preserve as much meniscal tissue as possible and to use meniscal-preserving techniques, such as repair, when feasible, especially in patients with high physical demands (3,27).

Yet, meniscectomy has arguably a short-term benefit of a faster return to football. Pain and joint effusion should be addressed immediately after surgery, while early full weight-bearing, immediate full ROM are recommended (28). Muscular and neuromuscular deficits need to be addressed and resolved before return to sport (23). The most relevant muscular and neuromuscular deficits to consider and resolve are lower extremity kinetic chain [not just knee flexors and extensors] and the lumbo-pelvic-hip complex, basic motor patterns deficits on the frontal and the sagittal plane [limb stability, pelvis and trunk stability, shock absorption strategies] (29).

Football players showed a shorter time to return to play for medial meniscectomy if compared to lateral [5 *vs.* 7 weeks] and a 6 times higher probability of returning to play (30). Lateral meniscus injuries are more challenging clinically, even in case of partial meniscectomy.

Meniscus repair and considerations for rehabilitation

Findings from a recent systematic review reported highly variable postoperative rehabilitation protocols following isolated meniscus repair (31). Despite the variability in the rehabilitation protocols, there were no differences in failure rates, patient reported outcomes and RTS rates for vertical meniscus tears (31). The evidence from this systematic review is inconclusive as 78% of the studies were retrospective, involved for the majority vertical longitudinal tears of the medial meniscus and lacked details for the rehabilitation (31).

From a biomechanical perspective, it is eminent that the type and location of the lateral meniscus tear and the subsequent repair dictates the post-operative protocol. For example, it has been suggested that meniscal tears with stable or unstable patterns receive different indications regarding postoperative loading in the early stages of rehabilitation (14). Early weight bearing can be allowed in more stable tear patterns (i.e., vertical longitudinal tear) (32). Conversely, in case of unstable tear patterns (i.e., radial, complex, and posterior root tears) early weight bearing can create distractive forces (33) and subsequently, non-weight bearing in the early phases has been advocated. For example, 6 weeks of non-weight bearing followed by 3 weeks of progressive loading for a lateral meniscus root repair (34).

As a lateral meniscus injury is commonly associated with a concomitant ACL injury, this has important implications for the surgical treatment to reduce failure rates. Biomechanical data have demonstrated the forces applied on the meniscus to increase up to 200% in the ACL deficient knee, suggesting an increased failure rate following meniscal repair in an ACL deficient knee (35).

When performing a lateral meniscal repair, especially in conjunction with ACL reconstruction, the ACL rehabilitation program should be adjusted to the meniscus repair, however there is no consensus on the ideal

rehabilitation path or return-to-play protocol (36). In general, there is a trend towards longer rehabilitation time, to assure optimal conditions for the healing meniscus (37).

In the following sections we will briefly discuss the concept of evidence-based rehabilitation that has been applied to athletes after ACL injury. A framework based on current literature will be presented on how this concept can be applied for the rehabilitation of athletes with lateral meniscus injuries.

Criteria-based rehabilitation

Della Villa and colleagues (38) presented a rehabilitation framework strategy for the patient after meniscal surgery. In the field of sports medicine and orthopedic rehabilitation, a holistic approach to the joint and to the patient should be applied. The final goal of each rehabilitation process should be a complete functional recovery while minimizing the risk of re-injury. Functional recovery has been achieved in case of satisfactory clinical parameters (absence of pain and swelling, normal stability and range of motion), functional recovery (restoration of strength and endurance), biomechanical (good movement quality), psychological (no fear of reinjury, confidence), and sport specific (ability to handle volumes and work intensities in training) factors (39).

This is achieved with a true teamwork approach. In this scenario, surgery and functional recovery are part of the same "injury to recovery process" (38).

As discussed, different surgical procedures require a different rehabilitation progression, and the timing of recovery is very different. Recent literature showed that RTS times are highly variable based on patient-specific and sport-specific factors in addition to the type of meniscus surgery performed, ranging from 7–9 weeks after isolated meniscectomy to 5.6 months with meniscal repair, and the time to RTS was reported to be longer for athletes who required concurrent ACLR (40).

Rehabilitation should begin early, be progressive whilst constantly monitoring the knee. A multidisciplinary approach is key in the recovery process. During rehabilitation the patient is part of a team including the orthopedic surgeon, the sports medicine physician, the sports physiotherapist and athletic trainer (38).

Close communication between the surgery team, the rehabilitation team, and the patient, explaining the rehabilitation goals, monitoring progression, and properly managing possible complications, is key for successful recovery and RTS (38).

Ultimately, RTS is a continuum in which the athlete completes a stepwise functional recovery process, with objective data [including knee homeostasis (swelling), knee range of motion (ROM), movement quantity (muscle strength), movement quality (whole body biomechanics) and cardiovascular fitness] justifying the return to activities that will be progressive.

Our rehabilitation protocol is divided into functional steps, consisting of treatment goals and specific interventions. To proceed from one step to another, patients should pass established clinical and functional criteria [green traffic lights] For example, entrance criteria to start on-field rehabilitation are: (I) no knee pain or swelling, (II) no subjective knee instability, (III) negative knee laxity tests with concomitant ACLR, (IV) a minimum of 80% limb symmetry during isokinetic assessment of knee flexor and extensor strength, (V) good movement quality (ideally, assessed qualitatively with video analysis) in basic foundation movement exercises, and (VI) ability to run aerobically for greater than 10 minutes at 8 km/h with normalized running mechanics (ideally, assessed qualitatively with video analysis).

This concept has been presented in previous papers on RTS after ACLR (28,41) and the same principles apply to every sport patient following knee surgery.

Rehabilitation stages after lateral meniscus surgery

In the following sections we will outline in detail which are the goals and respective interventions in the three stages of rehabilitation. However, the most important principle is to manage the progressive increase in loading through multiple measurements including medical control consultations and functional tests detailing movement quantity and quality. The functional evaluation of the player ideally comprises (I) strength test (e.g., knee isokinetic testing at low and high angular velocity), (II) qualitative movement evaluation (e.g., frontal and lateral evaluation of jumping and cutting task), (III) cardiovascular fitness test (e.g., aerobic and anaerobic threshold test).

Early-stage rehabilitation

Pain, swelling, range of motion, strength are the key areas to address in this stage. Hydrotherapy and gym exercise with core stability training and basic lower limb strengthening are used to achieve early-stage functional

Figure 1 Example of hydrotherapy exercise following meniscal repair. Early introduction of sport-specific exercises can be useful. This image is published with the participants' consent.

criteria.

It is important to prepare the patient for the mid-stage rehabilitation, to avoid loading a painful, swollen, and unprepared knee (42). The most important aspect is minimizing the decrease in quadriceps strength and impairment in function (29). Difficulties in restoring knee extensor strength could be due to arthrogenic muscle inhibition (AMI) after injury and surgery (29). Therefore, managing pain and swelling is important, as they will negatively contribute to AMI (43). Cryotherapy, medication and transcutaneous electrical nerve stimulation (TENS) have been shown to reduce AMI (44). The utilization of neuromuscular electrical stimulation and cross-education is important to enhance activation of the quadriceps to support recovery of knee extensor strength (45). Recovery of complete knee extension serves as the necessary foundation for quadriceps activity as well to restore a normal gait pattern. In this context the use of hydrotherapy is very useful to manage the appropriate loading post-surgically (46) and to gradually add more complex exercises (*Figure 1*).

Mid-stage rehabilitation

Mid-stage is a critical step in every rehabilitation program and entails three different areas.

The first key area in mid-stage rehabilitation is muscle strength, not only for knee spanning muscles [quadriceps and hamstrings] but for the entire lower extremity kinetic chain and lumbo-pelvic-hip complex. Aiming for a successful RTS, it is necessary for an athlete not only to resolve impairments at the knee, but also to restore global neuromuscular function, sports-specific movement quality and sport-specific readiness [fitness, technical training, and load readiness] (39,47,48). To achieve this, return to performance should be a primary focus from the start and throughout the whole rehabilitation process (49).

Knee extensor strength by the end of mid-stage rehabilitation should be within 20% of the contralateral limb (42). Deficits greater than 20% are linked with reduced knee function (jump distance) and movement compensations (unloading the involved knee) during jump landing tasks (50).

Strengthening includes isolated open chain exercises [e.g., leg extension] as well as closed chain strengthening exercises [e.g., squatting, deadlifting, step-ups, lunges] (29). Based on a systematic review on rehabilitation after vertical/longitudinal tears and radial tears, open kinetic chain quadriceps strengthening can be started at 6 weeks and progressive starting at 12 weeks (31).

Leg press and squatting should not exceed 90 degrees of knee flexion in the first 3 months (31).

For a detailed overview on type of exercises and strength training parameters like volume, frequency and intensity we refer to the reader to previously published work (29).

It is crucial not to ignore the contralateral uninjured limb, focusing on rehabilitation of the injured limb only. It is important to recognize that neuromuscular function deficits following knee surgery are typically bilateral, in which the contralateral limb is weaker than its pre-operative values (51).

Evidence suggests that high-intensity eccentric training of the contralateral limb may be more effective than concentric training, in terms of the cross-education benefit (52).

It is also recommended when measuring knee extensor strength as part of the functional recovery process, or prior to RTS to consider both the relative [e.g., Limb Symmetry Index] and absolute strength of the injured limb. We recommend, based on both evidence (53) and clinical experience, limb symmetry index of 80% for knee extensor strength [compared to the contralateral limb] and >2 Nm/kg^{-1} isokinetic peak torque at $90°/s^{-1}$] be achieved prior to progressing to the late-stage rehabilitation and RTS program (54).

The second key area is movement quality assessment and improvement with targeted neuromuscular training addressing altered basic movement patterns. Technology for movement analysis is readily available clinicians using apps on smartphones (Kinovea, Hudl, Coaches Eys etc.). It is important that strengthening during mid-

Figure 2 Example of neuromuscular training with visual biofeedback to target movement quality before progressing to on field rehabilitation. The patient is performing a single leg squatting task with proper frontal plane alignment in a indoor space dedicated to motor learning (Isokinetic Green Room) consisting in a system of high speed cameras, force platform and a video-wall to ensure comprehensive biofeedback. This image is published with the participant's consent.

stage rehabilitation is focused both distally and proximally to the knee joint. Deficits in plantar flexor strength and lumbo-pelvic region strength can impact lower extremity movement quality (42).

Furthermore, restoring symmetrical and optimal movement quality in basic motor tasks (such as walking, going up and down stairs) is important. For example, criteria for walking include physiological knee flexion-extension ROM, symmetrical stance phase at normal preferred gait speed for the athlete. Importantly, failure to sufficiently resolve movement quality during basic functional tasks (when compared to highly complex sporting actions such as cutting mechanics) early post-ACLR can have marked impact on movement quality during late-stage rehabilitation and at the time of and after RTS. We conduct a Movement Analysis Test (M.A.T.) that consists of 2D frontal and lateral evaluation of six sport-specific patterns with high-speed cameras and is exported to software for movement analysis. The series of six movements are evaluated according to five objective criteria. The result is considered optimal if the test score is ≥90%.

The third key area is fitness re-conditioning, to commence late-stage rehabilitation with an adequate physical fitness profile (42).

It is essential that an athlete begins this stage with a sufficient physical fitness profile. Fitness re-conditioning goals should be targeted on the athlete's sport, profile, and previous injury history. For most patients it is recommended incorporating specific sessions of re-conditioning that include a focus on body composition, upper body morphology and strength, and importantly cardiovascular conditioning (42).

This could include either incorporation of this work into the patient's existing rehabilitation training or separate re-conditioning sessions, involving predominantly non-load-bearing upper body strength work, low or no load cardiovascular training [e.g., deep water running in swimming pool, stationary bike, cross-trainer, Anti-Gravity Treadmill, etc.] and additional corrective strengthening [e.g., extra 'lumbo-pelvic-hip strength session' focusing on areas of weakness] (42).

Late-stage rehabilitation

The ultimate goal of late-stage rehabilitation is the recovery of the sport specific capacities, and the main rehabilitation environment is the field. Late-stage rehabilitation aims to optimize neuromuscular and movement performance and to achieve return-to-sport, defined as a continuum of sport-specific on-field rehabilitation, return to training, return to play and finally return to performance (47,54,55).

It has been reported that patients often return to sport with non-optimal training levels, with deficits in neuromuscular function and movement quality, insufficient sport-specific conditioning, and ultimately lower performance levels (54).

Thus, the RTS training process should be individually targeted, sport specific with a sufficient, monitored training volume to reduce the likelihood of acute or sub-acute overloading.

Neuromuscular function, movement quality, sport-specific conditioning, training load need to be effectively implemented into late stage rehabilitation, which should involve gym-based re-conditioning, functional movement re-training, and on-field rehabilitation (54).

Return-to-sport testing needs to be comprehensive and interdisciplinary, incorporating state of the art tests, to achieve recovery of sport-specific fitness, optimal movement quality (*Figure 2*) and on-field load progression (*Figure 3*) (54). For a more detailed overview, the interested reader is referred to Buckthorpe *et al.* (39,48).

Clinically relevant summary

Partial lateral meniscectomy may allow for more rapid

Figure 3 Example of on field rehabilitation exercise for football. On field rehabilitation is a complex program divided into 5 main stages according to Buckthorpe *et al.* (39). This image is published with the participants' consent.

return to sport than meniscal repair, but there is significant risk of future cartilage degeneration (56). This should be discussed with the athlete.

The lateral meniscus is not the same as the medial meniscus: mean time for return to sport is significantly longer in patients undergoing partial lateral meniscectomy when compared with those undergoing medial meniscectomy (30).

Postoperative rehabilitation after lateral meniscus repair should be adjusted to ensure meniscus healing as high compressive and shear forces can disrupt the meniscus repair healing process (57).

Strengthening exercises after lateral meniscus repair should be initially be done in restricted ROM depending on tear location and on surgeon's discretion (38).

A criteria-based rehabilitation protocol, divided into functional steps, consisting of treatment goals and specific interventions, should be followed (38).

Location and size of tears and associated surgeries, such as ACLR, osteotomies and cartilage procedures, will further change the rehabilitation program (36).

Patient characteristics like age, type and level of sports and goals have to be taken into account (38).

The clinical examination is integral part of the RTS decision making and includes assessment of swelling, joint line tenderness and meniscus tests.

Close communication between the surgeon team, the rehabilitation team and the patient, explaining the rehabilitation goals, monitoring progression, and properly managing any complications, is essential for successful recovery and return to sport (38).

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Footnote

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