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Review Article

Anterior Cruciate Ligament Reconstruction and Return to Sports: A Comprehensive Guide

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Abstract

Anterior cruciate ligament (ACL) injuries are common in sports, particularly in activities involving jumping, pivoting, and sudden direction changes. While non-surgical treatment options are available for some patients, ACL reconstruction surgery is often recommended for athletes who wish to return to their pre-injury level of activity.

The article also examines the factors that may affect an athlete's ability to return to sports following ACL reconstruction. The factors contributing to this phenomenon include surgical intervention, common complications of ACL reconstruction, and rehabilitation. The article examines the significance of implementing a thorough rehabilitation program that encompasses activities aimed at enhancing strength, flexibility, and balance.

The review concludes by summarising the main themes explored and emphasizing potential avenues for future research. Although ACL reconstruction has demonstrated a considerable rate of success and facilitates the return to sports, there remains a significant knowledge gap about the enduring consequences of the procedure and the determinants that influence the return to sports.

This review article provides a comprehensive overview of ACL reconstruction surgery and return to sports. It highlights the importance of a multidisciplinary approach to rehabilitation, which should include physical therapy and psychological support. Healthcare professionals can better support athletes in their recovery and help them achieve their goals by understanding the factors that influence return to sports after ACL reconstruction.

INTRODUCTION

Anterior Cruciate Ligament (ACL) injuries are common among athletes, particularly those involved in high-impact sports such as soccer, basketball, and football. These injuries can be debilitating, often requiring surgical intervention and extensive rehabilitation. ACL reconstruction (ACLR) is a common surgical procedure to restore knee stability and allow athletes to return to sports activities after an ACL injury. The decision-making process regarding when it is safe for athletes to return to sports after ACLR is complex and multifactorial. Several factors contribute to the successful return to sport after ACLR. Brinlee et al. [1] conducted a clinical review incorporating contemporary evidence and direct clinical data from a university-based practice. They discovered that the inclusion of regular quadriceps strength assessments, a prolonged timeline for returning to sports activities, the immediate implementation of open kinetic chain exercises, the use of criterion-based progressions for different activities such as running, sprinting, and plyometrics, as well as the implementation of secondary prevention programs, resulted in enhanced patient outcomes and a reduced likelihood of recurring injuries. Return to sports after ACLR requires careful consideration of various factors, including rehabilitation protocols, psychological readiness, physical impairments, function assessments, time since surgery, graft type used in reconstruction surgery [2], fear of re-injury [3], and performance outcomes [4]. Incorporating evidence-based practices such as frequent quadriceps strength testing and criterion-based progressions can improve patient outcomes. Psychological readiness evaluations are also important in determining an athlete's preparedness for RTS. Future research is needed to validate these criteria further and develop comprehensive guidelines for a safe return to sport after ACLR.

This review provides evidence on various aspects of ACLR and the return to sports. Key findings include the importance of incorporating the latest research into rehabilitation guidelines to improve patient outcomes and decrease the risk of re-injury [5]. Factors such as quadriceps and hamstring strength, movement quality deficits, psychological readiness, time since surgery, and functional tests are associated with successful return to sport [6]. Prehabilitation programs that include muscular strength, balance training, and perturbation training can benefit patients after ACLR [7]. Graft selection is an important consideration in ACLR surgery [8]. Fear of re-injury is a common psychological response after ACL injury that can negatively affect rehabilitation outcomes [9].

Surgical Intervention: ACL Reconstruction

ACL injuries are common ligament injuries that can have significant consequences for individuals, particularly athletes [10]. ACLR has been the standard treatment for many years [11], but there is increasing interest in primary repair as an alternative approach [12]. This section aims to provide an overview of the available evidence on surgical intervention for ACLR and address key questions related to anatomy, physiology, biomechanics, management, rehabilitation principles, meniscus repair combined with ACLR, and outcomes.

Anatomy and Physiology of ACL Reconstruction

ACLR is a surgical procedure that replaces a ruptured anterior cruciate ligament within the knee joint. The ACL is a prominent ligament within the knee joint that stabilizes the joint and limits excessive anterior translation of the tibia concerning the femur. The ACL comprises two primary bundles, namely the posterolateral and anteromedial bundles, which transmit forces across the knee joint [10]. The tearing of ACL has been associated with the development of knee instability and the experience of pain. In ACLR, a graft is employed as a substitute for the damaged ligament. The graft can be obtained from various sources, including the patient's hamstring tendons or patellar tendon, as well as from a donor. The graft is then placed in the same position as the original ACL and secured with screws or other fixation devices. Over time, the graft will heal and integrate with the surrounding tissues, providing stability to the knee. Women are more prone to ACL injuries due to anatomical factors such as narrower intercondylar notch width and increased quadriceps angle [10]. A comprehensive comprehension of the knee's anatomical and kinetic aspects is necessary to make informed surgical decisions that can significantly impact the resulting outcomes.

Biomechanics of ACL Reconstruction

The magnitude of forces transmitted through the ACL exhibits variability depending on the position of the knee joint [10]. Surgical techniques aim to restore proper knee function by restoring stability and preventing further injury. Single-bundle versus double-bundle repair is a choice that must be made based on individual patient characteristics [10]. Additional options to consider involve whether to retain the damaged ACL remnant within the knee or choose the appropriate type of graft tissue and technique for its implantation [10].

Management of ACL Reconstruction

It is important to have surgical intervention in order to restore stability to the knee that has been injured and to prevent any potential damage to the meniscus. Nevertheless, it is important to note that certain patients may not meet the surgical intervention criteria due to concurrent medical issues [10]. The knee is susceptible to additional injury without surgical intervention as instability continues [10]. Recent advancements in surgical procedures have been devised to effectively restore optimal knee functionality, enabling athletes to recommence their professional pursuits [10].

Rehabilitation Principles of ACL Reconstruction

Following ACL surgery, it is imperative to undergo rigorous postoperative physical therapy to restore functionality to the injured extremity [11] effectively. Rehabilitation protocols vary depending on the technique used for ACL repair, such as internal bracing or dynamic intraligamentary stabilization [11]. Further investigation is warranted to ascertain the adaptations physical therapy must undergo in response to these unique mending approaches [11].

Meniscus Repair Combined with ACL Reconstruction

Meniscal tears that are concomitant with ACL tears, including root tears and ramp lesions, are frequently observed, but they may be more challenging to identify on magnetic resonance imaging (MRI) when compared to other types of tears [13]. The prompt therapy administration for these rips has been demonstrated to enhance outcomes when performed with ACLR. Different techniques are preferred based on tear patterns and the chronicity of the injury [13].

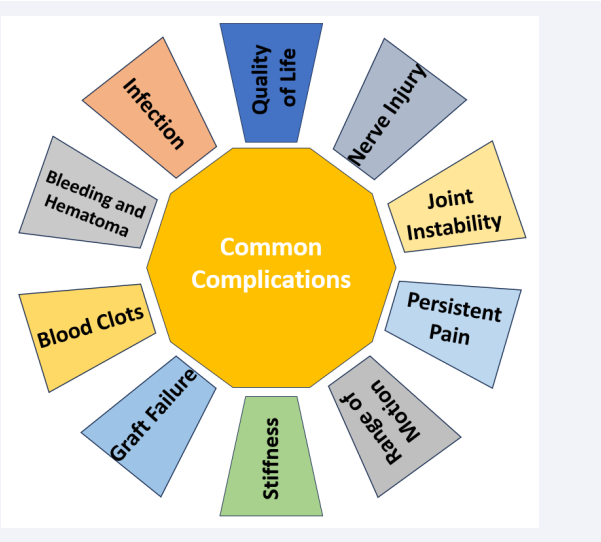
Outcomes of ACL Reconstruction

Several studies have reported good short-term results for primary repair of the ACL; however, high-quality evidence for long-term outcomes is lacking [12]. Augmented primary repair techniques show promise in achieving non-inferior patient-reported outcomes compared to traditional autograft ACLR at two years follow-up [14]. However, more research is needed to validate these findings and optimize long-term outcomes.

In summary, surgical intervention plays a crucial role in managing ACL injuries. Understanding the anatomy, biomechanics, and management options allows for informed decision-making regarding surgical technique selection. Rehabilitation principles should be tailored based on individual patient characteristics and innovative repair techniques. Meniscus repair combined with ACLR improves outcomes. Long-term studies are needed to assess the effectiveness of primary repair compared to traditional reconstruction methods.

Common complications of ACL reconstruction surgery

While ACL reconstruction surgery is generally safe and successful, there are potential complications and risks associated with the procedure. These can include:



1. Infection

There is a risk of infection at the surgical site. This risk is relatively low but can occur. Knee joint infection following ACLR is infrequent but can potentially have severe consequences, with reported incidence rates ranging from 0.14% to 1.70%. The selection of graft type has been found to potentially correlate with the risk of infection, with studies reporting a higher risk for hamstring autografts compared to bone-patellar tendon-bone (BPTB) autografts, as well as a higher risk for allografts compared to autografts [16, 17]. Infections may require antibiotic treatment or, in severe cases, additional surgical intervention.

2. Bleeding and Hematoma

During and after surgery, there is a risk of bleeding. In some cases, excessive bleeding can lead to the formation of a hematoma, which is a localized collection of blood. In their study, Lamo-Espinosa et al. documented the case of a 27-year-old male patient who underwent a single-bundle ACLR procedure using a bone-patellar tendon-bone (BPTB) allograft. On a subsequent day following the surgical procedure, the patient exhibited signs of active pulsatile haemorrhage and experienced swelling in the knee [18]. The arthrocentesis procedure revealed the presence of haemarthrosis, and a total of 60 cc of blood was successfully collected. Following the contrast administration, the inferior lateral genicular (ILG) artery injury was identified and subsequently treated with selective embolization [18]. Large hematomas may need to be drained to relieve pressure and prevent complications.

3. Blood Clots

Surgery, immobilization, and reduced mobility during the recovery period can increase the risk of blood clot formation (deep vein thrombosis). Blood clots can be serious if they travel to the lungs (pulmonary embolism). Measures such as early mobilization, compression stockings, and blood-thinning medications may be used to reduce this risk.

4. Graft Failure

There is a small risk of graft failure, where the reconstructed ligament does not heal properly or fails to provide stability to the knee joint. A prospective study [4] evaluated complications after ACLR and their relation to the type of graft used. The overall incidence of complications was 39%, with a surgical revision rate of 28%. The incidence of hardware-related complications was higher in individuals who underwent hamstring transplants than those who received patellar tendon grafts [19]. The selection of graft type can potentially influence the incidence of problems following ACLR. Patellar tendon grafts were associated with a lower risk of graft rupture and problems with hardware material compared to hamstring grafts [19]. Graft failure may require additional surgery or revision ACLR.

5. Stiffness and Range of Motion Issues

Some individuals may experience stiffness or difficulty regaining the full range of motion in the knee after surgery. Yazdi et al. [20] provide Level II evidence supporting that the hyperextension manoeuvre may have a short-term effect on improving the range of motion after ACLR surgery. Singh et al. [21] present a case report of a young gentleman who developed loss of knee extension due to a cyclops lesion after ACLR surgery. This can be managed with physical therapy and rehabilitation exercises to improve flexibility and joint mobility.

6. Persistent Pain

While pain after surgery is normal and expected, some individuals may experience persistent or chronic pain in the knee joint. This can be due to various factors, such as nerve irritation, scar tissue formation, or other underlying conditions. Pain management strategies, including medications, physical therapy modalities, and further evaluation, may be necessary to address persistent pain.

7. Joint Instability

Sometimes, individuals may experience instability or giving way in the knee joint after ACLR. This can occur due to inadequate graft fixation, improper surgical technique, or concurrent injuries. The clinical outcomes of ACLR did not demonstrate superior results regarding knee functional scores and stability evaluations [22]. Further evaluation and potential additional treatment may be required to address persistent instability.

8. Nerve or Vascular Injury

While rare, there is a small risk of nerve or blood vessel damage during surgery. Surgeons take precautions to minimize this risk, but in some cases, nerve injury or vascular complications may occur, leading to sensory changes, weakness, or other

symptoms. Injuries to the saphenous nerve, the sciatic nerve, and the common peroneal nerve are infrequent in surgeries involving ACL-R [23-25]. Immediate medical attention is necessary if such complications arise.

9. Quality of Life

Regarding postoperative neurocognitive disorders, Olotu [26] discusses alterations in cognitive functions following anaesthesia and surgery. Although not specific to ACLR surgery, this article highlights that perioperative cognitive decline can have long-term consequences for patients' quality of life.

It is important to discuss potential complications and risks with the surgeon before undergoing ACLR surgery. They can provide personalized information based on specific situations, as well as address any concerns or questions one may have.

REHABILITATION

The Key to Successful Return

Following ACLR surgery, a comprehensive rehabilitation program is crucial for returning to sports. Glattke et al. [6] conducted a systematic ACLR recovery and rehabilitation review using Level I or II studies published from 2012 to 2020. They discovered that expedited rehabilitation had shown efficacy in patients undergoing semitendinosus-gracilis grafts. However, blood flow restriction training combined with high-intensity exercise does not yield positive outcomes in the ACLR recovery process. The rehabilitation process often encompasses multiple phases, each dedicated to certain objectives and gradually increases in intensity.

Phase 1: Early Postoperative Period

During the initial phase, the primary goals are pain management, swelling reduction, and knee range of motion restoration. Physical therapy sessions may include gentle exercises to improve quadriceps activation, ankle pumps for blood circulation, and passive range of motion exercises.

The early postoperative period after ACLR is critical for rehabilitation to ensure optimal outcomes [27]. One aspect investigated is using femoral nerve block (FNB) as part of multimodal anaesthesia during ACLR [27]. The comprehensive analysis conducted by Swank et al. revealed a scarcity of evidence indicating that femoral nerve block (FNB) leads to a quantifiable decrease in quadriceps isokinetic strength in the initial postoperative phase. However, the research showed no impact of FNB on functional outcomes or the ability to return to sports six months after undergoing anterior cruciate ligament (ACL) repair [27]. An alternative method for improving the repair of the tendon-to-bone connection in ACLR involves the utilization of scaffold sleeves that are bio-printed in a three-dimensional manner and are infused with mesenchymal stem cells (MSCs) [28]. Park et al.'s study in a rabbit model demonstrated that this technique improved osteointegration between the tendon and tunnel bone [28]. This finding implies that the utilization of three-dimensional bio-printed scaffold sleeves containing mesenchymal stem cells (MSCs) holds promise for expediting the process of bone-tendon healing in anterior cruciate ligament (ACL) reconstruction. The timing of ACLR surgery also plays a role in postoperative outcomes. Petersen and Laprell's retrospective study compared early (within three weeks) versus late (after ten weeks). They examined the efficacy of ACLR in patients who presented with concurrent injuries involving both the MCL and ACL. The study revealed that delayed ACL repair led to reduced motion loss following rehabilitation, fewer re-arthroscopies due to extension loss, and improved Lysholm ratings compared to early reconstruction [29]. Shaw et al.'s survey of Australian hospitals found a lack of standard practice regarding quadriceps strengthening exercises during the in-patient period after ACLR [30]. Static quadriceps contractions were prescribed by most hospitals surveyed, while inner-range quadriceps exercises were used less frequently [30]. Finally, Laboute et al.'s retrospective comparison of specialized rehabilitation sessions after ACLR in high-level athletes found that repeated rehabilitation sessions resulted in better outcomes in terms of time to return to training and competition, resumption of sports activities at the former level, pain levels, and subjective scores [31]. This suggests that an iterative specialized rehabilitation approach may improve postoperative outcomes for high-level athletes.

In summary, the available literature suggests that utilizing femoral nerve block (FNB) in ACLR surgery may temporarily reduce quadriceps strength in the immediate postoperative phase. However, it does not appear to impact functional results or the ability to return to sports activities after six months [27]. The utilization of three-dimensional bio-printed scaffold sleeves containing mesenchymal stem cells (MSCs) can potentially augment the tendon-to-bone repair process [28]. Late ACLR may result in better outcomes than early reconstruction in patients with combined MCL and ACL injuries [29]. Rehabilitation protocols vary widely and do not align with scientific recommendations for exercise prescription during the early postoperative period [30]. Finally, repeated specialized rehabilitation sessions may improve outcomes in high-level athletes undergoing ACLR [31].

Phase 2: Strength and Stability

Once pain and swelling have subsided, the focus shifts towards regaining strength and stability in the knee joint. Physical therapy sessions may include exercises such as quadriceps strengthening, hamstring strengthening, balance training, and proprioceptive exercises to enhance joint position sense.

Several studies have investigated different aspects of ACL rehabilitation, including the effects of various interventions on strength, stability, and functional outcomes. Van Grinsven et al. suggests that an expedited treatment plan, which does not involve the use of postoperative bracing and instead prioritizes pain reduction, swelling, inflammation, restoration of range of motion, enhancement of strength, and improvement of neuromuscular control, offers significant benefits without compromising stability [32]. Kochman et al. conducted a systematic analysis review to examine the incorporation of supplementary physiotherapy interventions within conventional rehabilitation protocols following ACLR [33]. The review encompassed a total of ten studies that assessed the efficacy of several therapies, including Kinesio Taping, Whole-body vibration, Local Vibration Training, Trigger Point Dry Needling, High Tone Power Therapy, alternating magnetic field, and App-Based Active Muscle Training Program [33]. The majority of these therapies show enhancements in pain reduction, reduction of swelling, increased range of motion (ROM), improved knee muscle strength, or enhanced knee function after postoperative rehabilitation for anterior cruciate ligament (ACL) injuries [33]. The study conducted by Sasaki et al. examined the impact of an 8-week core-muscle training regimen on the neuromuscular control of the lower limb and trunk during jump landing and single-legged squatting [34]. According to the study, core-muscle training enhanced the lower limbs and trunk biomechanics. This improvement was observed through increased trunk flexion angle and decreased peak knee-valgus moment during both the drop-jump test and single-legged squat [34]. Markatos et al. reviewed the anatomy of the ACL and its importance in ACLR [35]. They summarized recent tendencies regarding the anatomy of the ACL and its surgical application in reconstruction procedures. They also emphasized the significance of considering anatomy in rehabilitation protocols to achieve a full range of motion and stability postoperatively. Jeong et al. conducted a study in which they found that an 8-week core-muscle-training program improved lower limb and trunk biomechanics. Specifically, the program increased trunk flexion angle, VM: VL activation ratio (vastus medialis to vastus lateralis), and H: Q activation ratio (hamstring to quadriceps).

Additionally, the program reduced knee valgus angle during the drop-jump test and single-legged squat [36]. Cvjetkovic et al. assessed isokinetic testing as an evaluation tool for rehabilitation outcomes after ACLR [37]. They found that isokinetic testing provided objective information about thigh muscle strength and imbalance, which is useful for determining the success of rehabilitation after ACLR [37]. The study conducted by Saki et al. [38] examined the correlation between postural stability and lower extremities performance in individuals who underwent ACLR. The researchers also assessed the influence of these variables on core stability, knee laxity, and muscle strength. Their research findings revealed a noteworthy association between postural stability scores and core stability tests in both the legs that underwent surgery and the unaffected legs. The study conducted by Thomas et al. [39] investigated the impact of ACL injury and reconstruction on lower limb muscular strength. They found decreased hip-extensor and -adductor strength preoperatively compared to postoperatively. Knee-extensor and flexor strength were lower in the injured limb preoperatively and postoperatively compared to uninjured limbs.

In summary, these studies provide evidence-based insights into various aspects of ACL rehabilitation, including optimal protocols, additional physiotherapy interventions, core stability training, lower extremity muscle strength, postural stability, and the relationship between knee joint power and stability. The findings highlight the importance of individualized rehabilitation programs focusing on reducing pain and swelling, regaining range of motion and strength, enhancing neuromuscular control, and improving functional outcomes for successful ACL rehabilitation.

Phase 3: Neuromuscular Control and Functional Training

In this phase, athletes improve neuromuscular control and functional movements specific to their sport. Exercises may include jumping, landing mechanics training, agility drills, and sport-specific movements. The goal is to enhance dynamic stability and prepare the athlete for the demands of their sport.

Research studies have demonstrated that incorporating neuromuscular control exercises into the rehabilitation program of individuals who have undergone ACLR can provide positive outcomes. These exercises have improved knee proprioception, enhanced muscle strength, and elevated functional capacity in these patients. Kaya et al. conducted a study which revealed that implementing a neuromuscular control workouts program yielded greater efficacy in mitigating the strength disparity between the operated knee and its counterpart. Conversely, a regular rehabilitation program effectively reduced the endurance discrepancy [40]. This suggests that incorporating neuromuscular control exercises into rehabilitation programs can help improve knee proprioception sense following ACL-R. Culvenor et al. evaluated various rehabilitation interventions aimed at addressing symptomatic, functional, clinical, psychosocial, quality of life, and re-injury outcomes in individuals with ACL and meniscal tear [41]. They discovered evidence of intermediate certainty that indicates the effectiveness of neuromuscular electrical stimulation in enhancing quadriceps strength. However, they also observed that postoperative knee bracing does not contribute to improved physical function and laxity [41]. The postoperative rehabilitation following ACLR necessitates the consideration of multiple factors. These factors encompass the management of pain and swelling, safeguarding the healing graft, reinstating a complete range of motion that is comparable to the unaffected knee, fortifying the stabilizing muscles, improving neuromuscular control, and gradually advancing towards the

performance of functional activities essential for the resumption of sports participation [42]. Wilk et al. highlighted the need for preoperative rehabilitation to prepare patients for surgery and postoperative rehabilitation programs focusing on strengthening exercises and proprioceptive and neuromuscular control drills [43]. The risk of second ACL injury may be reduced through targeted neuromuscular interventions that address modifiable postsurgical risk factors [44]. Di Stasi et al. revealed that many athletes experience significant neuromuscular impairments after undergoing ACLR.

Furthermore, these impairments have the potential to serve as indicators for the likelihood of a second ACL injury in adolescent athletes [44]. Feedback techniques targeting functional deficits following ACLR can improve motor learning and reduce re-injury risk by addressing neurophysiologic aspects of injury during rehabilitation [45]. Gokeler et al. suggested integrating external focus strategies, neurocognition, motor planning, unanticipated sensory processing, and load management into rehabilitation programs to enhance motor learning and control throughout the process [46]. Vascellari et al. determined that functional parameters, including core and lower extremity neuromuscular control, were deemed more suitable for making decisions on the preparedness of individuals for sport-specific rehabilitation [47]. Faltus et al. [48] proposed the integration of external emphasis on control methods, neurocognition, motor planning, unforeseen sensory processing, and load management into rehabilitation programs to maximize outcomes. Research has demonstrated that implementing a sports bridge program encompassing comprehensive neuromuscular control of the entire body, progressive resistance strength training, and agility training yields positive results in enhancing patient outcomes and reducing the likelihood of re-injury after ACLR.

In summary, the available evidence suggests that incorporating neuromuscular control exercises into rehabilitation programs following ACLR can improve knee proprioception sense. Numerous interventions, including neuromuscular electrical stimulation, open versus closed kinetic chain exercises, structured home-based versus structured in-person rehabilitation, cryotherapy, psychological interventions, and whole-body vibration, have enhanced quadriceps strength and self-reported functional outcomes. Rehabilitation programs should consider individualized factors such as concomitant injuries and surgical procedures. Targeted neuromuscular interventions can address modifiable postsurgical risk factors for second ACL injury. Feedback techniques targeting functional deficits can enhance motor learning during rehabilitation. Functional progression milestones based on objective criteria are more appropriate than time-based criteria for determining readiness for return to sports activities. Addressing neuroplasticity through neurophysiologic and neurocognitive approaches can optimize outcomes in ACL rehabilitation.

Phase 4: Return to Sports

The final phase involves a gradual return to sports-specific activities. This phase focuses on sport-specific training, such as cutting, pivoting, and sprinting. The Panther Symposium ACL Injury Return to Sport Consensus Group [49] issued consensus statements regarding the protocol for reintegrating athletes into sports following ACLR. The authors emphasized the importance of characterizing the process of return to sport by attaining the pre-injury level of athletic activity. They further advocated for a criteria-based progression, encompassing a gradual transition from return to participation to return to sport and eventually culminating in a return to optimal performance. A suggestion was made to use a multidisciplinary methodology for decision-making related to return-to-sport. This approach would involve integrating several components, including objective physical examination data, validated RTS tests, functional assessment, psychological readiness evaluation, and the consideration of biological healing and environmental factors. Athletes are closely monitored for any signs of pain or instability during these activities. Once they demonstrate adequate strength, stability, and confidence in their knee joint, they can be cleared to return to full sports participation.

The existing literature presents evidence-based guidelines for the rehabilitation of the ACL following surgical reconstruction. The comprehensive rehabilitation process ought to encompass a preliminary prehabilitation phase, followed by three distinct postoperative phases based on specific criteria: impairment-based, sport-specific training, and return to play [50]. Strength and hop tests are recommended to guide progression through these phases [50]. Postoperative rehabilitation should continue for 9-12 months [50]. Nutritional supplementation with gelatine and vitamin C may assist in optimizing return to play [51]. Perturbation training does not appear to provide additional benefits beyond strengthening, agility, and secondary prevention exercises in ACL rehabilitation [52]. Rehabilitation protocols should incorporate functional benchmarks rather than time-based milestones to evaluate readiness for return to sport [53]. Variability of leg muscle power and hop performance exists among patients following ACLR. Some individuals may reach the criteria for a safe return to sport based on maximal strength measures but still exhibit ongoing biomechanical deficits during functional tasks such as jumping or changing direction movements [54]. Compliance with postoperative rehabilitation is an important factor influencing the rate of return to sport after revision ACLR. Higher compliance significantly increases the chances of returning at the same pre-injury level [55]. Periodization can be effective in ACL rehabilitation by maximizing training adaptations while minimizing fatigue and injury. Progressive loading through periodized programming improves athletic skills such as muscular strength, endurance, and power compared with non-periodized training [56. The influence of quadriceps strength on patient function during late-stage ACL rehabilitation surpasses that of single-leg forward hop performance. Attaining a state of symmetrical performance in both strength and hop tests may not be deemed adequate for attaining optimal patient-reported function. [57].

Physiotherapists play a crucial role in ACL injury rehabilitation. They provide expert rehabilitation using a biopsychosocial

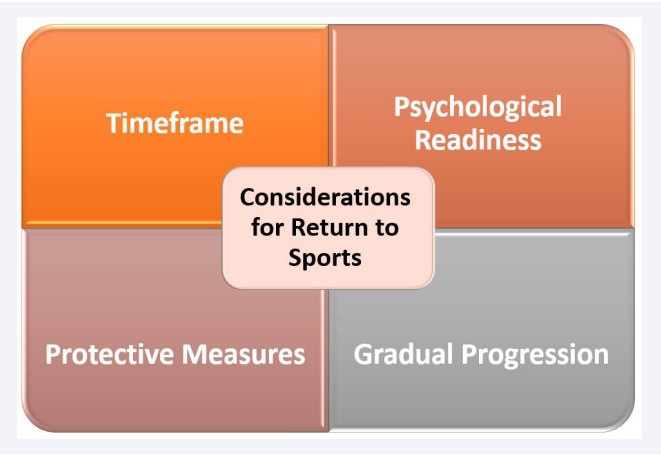
approach and evidence-informed practice. However, there is variability in treatment approaches, and further research is needed to clarify areas of uncertainty and improve the quality of rehabilitation that helps athletes return to sports.

CONSIDERATIONS FOR RETURN TO SPORTS

The surgical treatment known as ACLR is frequently conducted to restore knee stability and functionality following an ACL rupture. Nevertheless, determining the appropriate timing for an athlete's safe return to sports following ACL surgery is multifaceted and intricate. The objective of this study is to present a comprehensive analysis of the existing body of information about factors that should be taken into account when determining the appropriate timing for athletes to return to sports activities following ACLR surgery. Isokinetic and functional testing has been extensively employed in assessing postoperative rehabilitation progress following ACL surgery [58]. Functional tests, including hop tests, agility tests, and limb symmetry index, have been employed as evaluative measures to monitor the advancement of rehabilitation [58]. Neuromuscular electrical stimulation (NMES) superimposed on movement has been investigated as an additional treatment modality during early rehabilitation after ACL surgery [59]. Eccentric training programs, plyometric training programs, or both have been studied in post-ACL-surgical rehabilitation [60]. Platelet-rich plasma (PRP) therapy has been investigated as an alternative treatment option for ACL rupture [61]. The timing of return to sports after ACL surgery is a critical consideration. Several studies have assessed the factors that influence the timing of return to sports. Psychological readiness, subjective scores, clinical examinations, graft maturation on MRI, and functional performance testing have all been evaluated as potential predictors for return to sports after ACL surgery [62, 63]. However, no consensus exists on which factors are most reliable for determining when an athlete can safely return to sports. Regarding rehabilitation protocols, various exercise programs have been described in the literature. Closed-chain kinetic exercises have been suggested as more efficacious than open-chain exercises for ACLR rehabilitation based on limited evidence [64]. However, additional study is required to generate definitive proof supporting the advantages of closed-chain exercises. While a wealth of literature is available on considerations for returning to sports after ACLR, there are still gaps in knowledge and inconsistencies in findings. Future research should focus on standardizing test batteries, comparing test results with normative data, evaluating long-term outcomes following different rehabilitation protocols, and identifying reliable predictors for safe return to sports. Returning to sports after ACLR requires careful consideration of several factors:

1. Timeframe

The duration of rehabilitation varies depending on individual factors such as age, pre-injury fitness level, and surgical technique. The retrospective analysis conducted by Petersen and Laprell aimed to compare the outcomes of early ACL restoration (within three weeks) with late ACLR (after ten weeks) in patients who had combined injuries of the medial collateral ligament



(MCL) and ACL [29]. The researchers discovered that late ACLR led to reduced motion loss following rehabilitation, fewer re-arthroscopies due to extension loss, and improved Lysholm ratings compared to early reconstruction [29]. Typically, athletes can expect a recovery period of 6-9 months before returning to full sports participation.

2. Psychological Readiness

It is essential for athletes to feel confident in their knee joints and trust their surgical outcome before returning to sports. In terms of psychological readiness to return to sport after ACLR, Webster et al. [3] found that fear of re-injury is a commonly reported psychological response among athletes' post-injury. Fear of re-injury can negatively affect rehabilitation outcomes, such as physical impairments and function, as well as prevent successful RTS. Psychological support from sports psychologists or counsellors may be beneficial during this phase.

3. Protective Measures

Athletes may need protective braces or tape their knee for additional support during the initial return to sports phase. These measures can help reduce re-injury risk and provide a sense of security.

4. Gradual Progression

Athletes should gradually increase their training intensity and volume to allow their knee joints to adapt to the demands of their sport. Rushing the return process can increase the risk of re-injury.

CONCLUSION

Based on the comprehensive review of the available evidence, doctors should integrate regular and precise assessments of quadriceps strength into rehabilitation regimens for ACLR. Implementing delayed return-to-sport timelines, in conjunction with the immediate use of open kinetic chain exercise, is recommended. It is imperative to adhere to criterion-based progressions for running, sprinting, plyometrics, agility, cutting, and pivoting before resuming participation in competitive

sports. Furthermore, it is recommended to incorporate a secondary prevention program after resuming athletic activities. Rehabilitation programs must consider customized elements, including the selection of graft type, which should be based on patient features and expectations. It is imperative to complete a psychological readiness evaluation before permitting patients to resume participation in sports safely.

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