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Ideal Rehabilitation Programme after Anterior Cruciate Ligament Injury: Review of Evidence

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Abstract

Knee injuries are the second most common musculoskeletal injuries in primary care, with anterior cruciate the most commonly injured ligament. It is caused by contact / non-contact and accelerating/decelerating twisting injury of the knee. Typical presentation includes trauma with pain and swelling, with laxity of the knee joint. Management includes rehabilitation alone or surgery combined with rehabilitation. Pre-surgery rehabilitation with graded physiotherapy programme results in improved postoperative recovery, reduced pain, swelling, better stability and improved range of movement. No consensus exists on an ideal rehabilitation programme, as various factors, including injury to other knee structures, choice of graft, type of surgery performed and patient preference exist. Rehabilitation includes accelerated vs. conservative, closed vs. open kinetic chain and techniques involving bracing, neuromuscular training and cryotherapy. Ideal personalised rehabilitation plan should include educating athletes to improve adherence, providing realistic strategies and approximate time frame for a return to sport. Studies support accelerated rehabilitation before and after surgery, in a clinic and home setting, with combined kinetic exercises. Accelerated rehabilitation protocol involving exercises to increase muscle strength, knee ROM and proprioception along with reducing pain, inflammation and swelling can lead to better knee stability and a less complicated rehabilitation course.

Keywords: Anterior cruciate ligament, rehabilitation, knee injury, knee pain

Background

Knee injuries are the second most frequently occurring (after back injuries) musculoskeletal injuries in primary care (van Grinsven, van Cingel, Holla, & van Loon, 2010). The prevalence of knee injuries is approximately 48/1000 patients a year, 9% of which are ligament injuries, anterior cruciate ligament (ACL) being the commonest of these (van Grinsven et al., 2010). It is commonly injured in 15-25-year-old age group while the knee is slightly flexed and in external rotation (Beynnon, Johnson, Abate, Fleming, & Nichols, 2005b). ACL is the primary stabiliser of the knee joint with an injury causing the knee to become unstable. Management of this instability involves conservative or surgical options with rehabilitation before and after, being the most important part of the management (Beynnon, Johnson, et al., 2005b). Rehabilitation plays a significant role in determining how quickly and safely an athlete can return to sport (Cascio, Culp, & Cosgarea, 2004). There have been reports of shortening the careers of professional athletes for up to two years, along with a reduction in their performance by up to 20 % following ACL injuries (Wilk, Macrina, Cain, Dugas, & Andrews, 2012).

Materials and Methods

Searching online PubMed and Google scholar databases completed the review of the literature. The keywords used for searching included, “ anterior cruciate ligament”, “ruptured ACL”, “rehabilitation”, “open and close kinetic exercise”. All articles including original research, reviews, systematic reviews, randomised trials and meta-analyses were included, ranging from 1992 to 2015. Among the ACL rehabilitation articles reviewed, in this study, 12 are Level 1 or Level 2 studies that include meta-analyses, systematic reviews and randomised trials. The topics covered as part of this review includes mechanisms of ACL injury, types of ACL graft, accelerated rehabilitation, open and closed chain kinetic exercises, phases of rehabilitation, improving knee proprioception, role of cryotherapy in rehabilitation and return to sports after rehabilitation.

Anatomy of the Anterior Cruciate Ligament (ACL)

ACL is a band of connective tissue measuring approximately 38mm formed by multiple collagen fibres (Micheo, Hernandez, & Seda, 2010). It originates from a wide base on the anterior aspect of the tibia and inserts into the lateral condyle of the femur on its posteromedial aspect (Micheo et al., 2010). It has two bundles, Anteromedial (AMB) and Posterolateral (PLB) Bundle. Flexion of the knee causes lengthening of the AMB and shortening of the PLB (Duthon et al., 2006). Nerve supplying the ACL is the posterior articular branch of the tibial nerve while branches of the middle genicular artery are responsible for the blood supply (Duthon et al., 2006; Micheo et al., 2010). Anatomy of the ACL has great significance in the rehabilitation and reconstruction process. An appropriate reconstruction and comprehensive recovery would eventually enable the reconstructed ACL to mimic its original anatomy as much as possible, leading to improved functionality (Markatos, Kasetta, Lалlos, Korres, & Efstathopoulos, 2013).

Mechanism of ACL Injury

ACL is commonly injured in non-contact (60.8%) as compared to a contact (39.2%) mechanism (Xie et al., 2015). A study by Kobayashi et al. looking into the mechanism of ACL injuries concluded that "Knee-in & Toe-out" was the commonest dynamic alignment of the knee during the injury (49.5%) with other mechanisms being "Knee-out & Toe-in" and "Hyperextension" (Xie et al., 2015). They also stated that the tibia could be externally or internally rotated, with the knee in valgus position, at the time of a non-contact ACL injury. Contact injuries are commonly associated with a valgus stress with associated injury to the menisci and medial collateral ligament (Micheo et al., 2010). The meniscus is co-injured in up to 2/3rd of ACL injuries, with a bone bruise of the lateral femoral condyle and tibia plateau present in 92% of these cases (Wilk et al., 2012). Most common sports associated with ACL injury include football, skiing, basketball and rugby (Xie et al., 2015).

Presentation, Diagnosis, Grading and Initial Management of the Injury

An athlete who has injured or ruptured the ACL would commonly present with a twisting injury of the knee that might be contact or non-contact while they were accelerating or decelerating (Shelbourne & Rowdon, 1994), i.e., starting to run fast or slowing down to stop. There would be an audible `click` or `pop` like sound during the injury. The examination would reveal swelling of the knee due to haemarthrosis, a positive Lachman`s and pivot shift test with the loss of knee extension (Shelbourne & Rowdon, 1994). Investigation with an MRI scan would help classify the ACL injury as intact, partial tear or a complete tear (Ha et al., 1998). Immediate management post injury would be rest, ice, knee compression, analgesia and non-weight bearing to avoid any further damage to the knee structures. Most studies agree that surgical option is considered once the injured knee has achieved full range of movement (ROM) and neuromuscular control along with resolution of pain, swelling and inflammation (Beynon, Johnson, et al., 2005b; Karasel et al., 2010; van Grinsven et al., 2010).

Preoperative Rehabilitation

ACL injuries can be managed conservatively with graded physiotherapy programme. These involve gradually strengthening the Hamstring and Quadriceps muscles and improve the stability of the knee joint. Inadequate rehabilitation can leave the knee unstable thereby predisposing it to the development of early Osteoarthritis (Keays, Newcombe, Bullock-Saxton, Bullock, & Keays, 2010). Surgical management of the anterior cruciate ligament has made its reconstruction the commonest orthopaedic surgery performed (Shani, Umpierrez, Nasert, Hiza, & Xerogeanes, 2016). There is growing evidence for recommending rehabilitation before an ACL reconstruction surgery, which could lead to improved postoperative recovery (Wilk et al., 2012). Another benefit of a pre-operative rehabilitation is that the patient, with reduced knee pain and swelling and more stable knee with improved range of movement, becomes mentally and physically prepared to undergo ACL reconstruction (Wilk et al., 2012). Shelbourne and colleagues have suggested a minimum of 3 weeks of rehabilitation before surgery to be sufficient for improved outcomes after surgery (Shelbourne, Wilckens, Mollabashy, & DeCarlo, 1991). This approach has been supported by Wilkes and colleagues who mention patients achieve better symptom control and knee range of movement with smoother progression through the initial stages of postoperative

rehabilitation (Wilk et al., 2012). Malempati and colleagues recommend up to three physiotherapy sessions followed by exercise programme at home (Malempati, Jurjans, Noehren, Ireland, & Johnson, 2015). Grant and colleagues support providing informational videos to patients before and after surgery, that could improve the patient's psychological well-being and efficient rehabilitation (Grant, 2013). Use of knee braces, exercises, cryotherapy and electrical muscle stimulation is recommended during the phase of rehabilitation before surgery (Malempati et al., 2015; Wilk et al., 2012).

Postoperative Rehabilitation

Rehabilitation programs after ACL reconstruction over three decades ago were not as aggressive as recent rehabilitation programs (Wilk et al., 2012). ACL rehabilitation programs these days encourage early mobilisation, full extension of the knee, walk and weight bear as soon as possible with an early return to sport (Malempati et al., 2015; Wilk et al., 2012). The aim of these programs is to improve muscle strength and stability of the injured knee, achieved by muscle strengthening exercises along with exercises to improve joint proprioception. Studies indicate no consensus on an ideal rehabilitation programme (Beynon, Johnson, Abate, Fleming, & Nichols, 2005a), possibly due to different ACL surgical repair options (single or double bundle (van Grinsven et al., 2010) hamstring vs. patellar tendon graft) and surgeon's personal preference of various rehabilitation programmes. The options for rehabilitation include accelerated vs. conservative, closed vs. open kinetic chain and other techniques involving bracing, home-based rehabilitation, neuromuscular training (Grant, 2013) and Cryotherapy. Many studies favour accelerated rehabilitation programme (Beynon, Johnson, et al., 2005a; B. D. Beynon et al., 2011a; Beynon, Uh, et al., 2005) allowing the return to sport within six months. In contrary to this, a randomised trial by Frobell et al recommended conservative rehabilitation programme (Wright et al., 2015) which would permit active participation in sports within 9-12 months (van Grinsven et al., 2010). Better outcomes have been associated with adhering to rehabilitation programmes after surgery. A comprehensive rehabilitation programme would include simultaneous rehab in the clinic setting and at home, with more emphasis on rehabilitation at home and improving an athlete's adherence to the rehabilitation and exercise programme (Brewer, Cornelius, Van Raalte, Tennen, & Armeli, 2013). Brewer and colleagues have suggested psychological factors associated with poor adherence to home-based rehabilitation programmes (Brewer et al., 2013).

Considering a Postoperative Rehabilitation Programme

The rehabilitation plan following surgery largely depends on various factors including injury to other knee structures, choice of graft, the type of surgery performed and patient preference (Wilk et al., 2012). Other structures potentially damaged along with the ACL could include PCL, menisci and collateral ligaments (Wilk et al., 2012). Rodriguez-Merchan mentions the decision to operate immediately or delayed surgery has no significant impact on the rehabilitation outcome (Rodriguez-Merchan, 2015). Grafts are mostly of two types, allograft from another person and allograft that is the patient's tissue, tendon or muscle. Autograft is preferred (Rodriguez-Merchan, 2015; Vaishya, Agarwal, Ingole, & Vijay, 2015) as it is safer with faster graft healing but associated with additional healing from the second surgical site. Allograft, on the other hand, has less recovery and healing time with a shorter length of

hospital stay (Vaishya et al., 2015). The commonest used graft is the “autogenous patellar bone-tendon-bone (BPTB)” and “autogenous hamstring tendon” (Vaishya et al., 2015; Wilk, 2015). However, some surgeons prefer to use quadriceps tendon (Shani et al., 2016) or allografts (Shino, Inoue, Horibe, Nagano, & Ono, 1988) with results from two meta-analyses suggesting no significant benefit of autograft over allograft. The BPTB graft is preferred as the gold standard (Shani et al., 2016) along with the double-bundle technique gives better knee joint stability (Xie et al., 2015), at the cost of greater risk of arthrofibrosis and high morbidity (Rodriguez-Merchan, 2015). A meta-analyses by Xie et al. recommended hamstring graft, due to less risk of postoperative complications and reduced rotational stability as compared to the BPTB graft (Xie et al., 2015). However, some studies, including meta-analyses by Goldblatt et al. concluded that using either of these two grafts did not have a significant variation in outcomes (Aglietti, Buzzi, Zaccherotti, & De Biase, 1994; Denti, Vetere, Bandi, & Volpi, 2006; Goldblatt, Fitzsimmons, Balk, & Richmond, 2005). Various techniques have been tried to improve graft healing including the use of platelet rich plasma, without any ultimate benefit (Vaishya et al., 2015).

Studies favouring accelerated rehabilitation programme suggest that there is better graft healing, increased the range of movement and a reduced risk of laxity of the graft with early return to sport (Arna Risberg, Lewek, & Snyder-Mackler, 2004; Grant, 2013; Shaw, 2002; Wilk et al., 2012). However, more recent studies (Bruce D. Beynnon et al., 2011; Christensen, Goldfine, & West, 2013) including a randomised trial by Christensen et al and Beynnon et al, comparing both accelerated and conservative rehabilitation, suggested that knee laxity, proprioception, thigh muscle strength and improvement in functional performance are more or less similar in both methods (B. D. Beynnon et al., 2011b; Beynnon, Uh, et al., 2005)

Studies many years ago favoured closed chain kinetic exercises (Shelbourne, Klootwyk, & Decarlo, 1992) stating that they were more functional with reduced strain on the graft after the operation. A randomised study by Bynum et al also favoured such exercises due to better knee compression forces and more efficacious in acute phases of rehabilitation (Bynum, Barrack, & Alexander, 1995; Micheo et al., 2010). Some studies also suggested increased risk of laxity and pain in the injured knee following open chain exercises (Mikkelsen, Werner, & Eriksson, 2000). Other studies (Seto, Orofino, Morrissey, Medeiros, & Mason, 1988) showed that patients treated with only closed chain exercises had weaker quadriceps strength thus making accelerated rehabilitation difficult (Mikkelsen et al., 2000). However, most studies reviewing randomised controlled trials of knee rehabilitation including a systematic review by Risberg et al (Fleming, Oksendahl, & Beynnon, 2005; Risberg, Mork, Jenssen, & Holm, 2001) suggest that there is no increased knee laxity with open chain exercises. They suggest that both open and closed kinetic chain exercises have the same effect on knee pain, laxity and function and favour a combination of both practices (Fleming et al., 2005; Mikkelsen et al., 2000; Perry, Morrissey, King, Morrissey, & Earnshaw, 2005) to achieve better quadriceps strength. Grant and colleagues suggest an all-inclusive rehabilitation strategy with home and institution based rehab, joint injections, neuromuscular rehab and cycling with the uninjured leg supported by educational videos (Grant, 2013). Shelbourne and Nitz (Shelbourne & Nitz, 1990) recommend exercises with both bearing weight and without bearing any weight, with the former being associated with less painful and more stable knees with an earlier return to sports.

Accelerated rehabilitation strategy involves both open and closed chain exercises. Individual tests are recommended to evaluate the knee and clear the progression through various phases of recovery. These tests are namely: International Knee Documentation Committee Subjective Knee Evaluation Form, Isokinetic strength test and hop test (Wilk et al., 2012).

Phases of Postoperative Rehabilitation

Rehabilitation after ACL surgery can be divided into four to five phases (Wilk et al., 2012) as follows:

Phase 1 - Immediate Postoperative Phase (Week 1): The main aim during this stage is to work towards achieving full weight bearing, passive knee ROM and reduce post-operative complications by reducing any swelling, pain and inflammation. Wilkes and colleagues suggest initial weight bearing with the help of a drop-lock knee brace to support early ambulation (Wilk et al., 2012). There is a conflict in the literature regarding this with some studies supporting the use of brace post surgery (Birmingham et al., 2001) with other studies not recommending bracing (Grant, 2013; Lindstrom, Wredmark, Wretling, Henriksson, & Fellander-Tsai, 2015; Wright et al., 2015) suggesting no significant relief of pain and swelling or improved range of joint movement. Cryotherapy and electrical muscle stimulation can also be practised during the first week for pain relief (Wilk et al., 2012) and stimulating contraction of the quadriceps muscle. It is essential that exercises to mobilise the patella in all directions are also included to avoid inhibition of the quadriceps and reduced ROM. Isometric open and closed chain exercises like straight leg raise with a pillow under the heel, knee flexion, extension and heel slide can be commenced without adding any additional weight. These activities can increase the possibility of full weight bearing and walk in 10 days without using any crutches (van Grinsven et al., 2010). Before moving on to phase 2 it is important to make sure that knee can be fully extended passively, flexion is possible up to 90 degrees, the leg can be raised in all directions, the patella is mobile and the athlete can walk (with or without crutches) (Malempati et al., 2015; van Grinsven et al., 2010; Wilk et al., 2012).

Phase 2 - Early Rehabilitation Phase (week 2 -10): Aim of this stage is to improve proprioception, achieve complete passive knee extension and gradually increase the strength of the hamstring and quadriceps muscles. Some studies further divide this phase into a controlled ambulation or strengthening phase (week 4 – 10) (Malempati et al., 2015; Wilk et al., 2012). During this stage, rehabilitation involves a combination of both open and closed chain isokinetic (Beynon, Johnson, et al., 2005a; Ross, Denegar, & Winzenried, 2001) and isometric, isotonic exercises. MOON guidelines support the progression of athletes from one phase to another based on individual readiness and improvement in the function instead of following a specific time frame after surgery. In these guidelines, Wright and colleagues recommend commencing open chain quadriceps exercises from 6 weeks (Wright et al., 2015). Full extension of the knee and movement of the patella in all directions is performed along with a gradual increase in flexion. However, cryotherapy should be continued, during this phase, to prevent post-operative complications, control swelling and inflammation (Raynor, Pietrobon, Guller, & Higgins, 2005). It is recommended to discontinue the use of a brace at approximately four weeks after surgery (Wilk et al., 2012). Neuromuscular exercises improve proprioception in the injured knee starting with static and then moving slowly towards dynamic stability exercises (Beynon, Johnson, et al., 2005a; Cascio et al., 2004; Risberg et al., 2001; Wilk et al., 2012). These include plyometric and sports specific exercises and

balance training by adding unstable surfaces and removing the sense of vision (by closing the eyes). Van Grinsven et al have also discussed some exercises to improve gait during this stage. Suggestions include treadmill walking preferably from week 3, ergometer cycling, stepping machine, swimming and during the late part of this phase to walk in a straight line (van Grinsven et al., 2010). Before moving on to phase 3, aims achieved would include normal gait, full knee extension and flexion up to 130 degrees (van Grinsven et al., 2010), absence of any knee pain or swelling and able to hop (80% of the other leg) (Wilk et al., 2012)

Phase 3 - Advanced Activity Phase (week 10 – 16): The primary aim of this stage is to achieve optimal strength in the lower limbs and better neuromuscular control (Wilk et al., 2012). Arthrofibrosis is one of the commonest complications following ACL surgery. It is advisable to mobilise the knee and encourage the full range of movement to prevent arthrofibrosis (Cascio et al., 2004). The combination of both open and closed chain exercises with added weights during this phase can further increase the strength of muscles, stabilising the knee (Beynon, Johnson, et al., 2005a; Cascio et al., 2004). Proprioception can be considerably improved by plyometric and balancing exercises leading to increased strength of muscles and improve the efficiency of movements involving a sudden change in direction (Cascio et al., 2004). In addition to this, certain changes like making the surface unstable, altering the resistance, speed and complexity of exercise can further improve dynamic stability and proprioception (Risberg et al., 2001). During the late part of this phase, the athlete should be able to start running regularly and commence jogging after week 13 (Cascio et al., 2004; Risberg et al., 2001). Before moving on to the next step, it is important that the knee should be free from any pain or swelling and be able to extend fully and flex it (Wilk et al., 2012).

Phase 4 - Return to Activity Phase (week 16 – 22): Main aim during this period is to increase further the strength of muscles that stabilise the knee, improve stability and balance by proprioception exercises, and start sports specific exercises. These exercises involve movements with a sudden change of speed and direction while running. To prevent risk of any further injury, exercises to improve arthrokinetic reflexes are also introduced (Cascio et al., 2004; Risberg et al., 2001)

Follow-up

It is recommended to arrange a follow-up at six months and 12 months after surgery (Wilk et al., 2012) during which specific tests should be performed, namely: an isokinetic test, KT 2000 test and functional tests. These follow-up and tests determine the long-term effectiveness of rehabilitation and flag up any concerns like graft failure, joint instability and muscle weakness, which can be addressed early on to avoid any long term complications.

Return to Sports

There have been suggestions of different tests to determine the correct time for a return to sports. In their review study, van Grinsven et al. have suggested tests, which should form part of an evidence-based rehabilitation programme when evaluating the time to return to sports. These tests include goniometer, visual analogue scale, hop test, circumference measurement with measuring tape, International Knee Documentation Committee Subjective Knee Form (IKDC) and isokinetic tests. Athletes can return to sports if they achieve the following:

absence of any knee pain or swelling, full knee extension and flexion, more than 85% hamstring and quadriceps strength (Wilk et al., 2012) with less than 15% difference between them in the injured knee as compared to the normal knee. Caution should be advised while interpreting these tests results for advocating the return to sports since they are not performed in fatigued situations. Wilk and colleagues recommend a gradual return to sports like football and tennis six months after and basketball up to 9 months after the ACL reconstruction (Wilk et al., 2012). However, an individualised approach should be adopted while recommending return to sports instead of a standard timeline (Malempati et al., 2015)

Conclusion

From the above discussion, it is evident that an ideal rehabilitation programme should include educating the athletes regarding the rehabilitation programme, providing realistic strategies and an approximate time frame for a return to sport. During the phases of recovery, it is essential that the goals of each stage have been accomplished before athletes move on to the next step. There are tests to confirm this at the end of each phase. Hence, rehabilitation has to be tailored to the needs of an individual and can take shorter or longer than the 22 weeks. There is increasing evidence that open chain exercises enhance the strength of the quadriceps muscle, but no clarity of exactly when to introduce these open chain exercises. More research is needed to determine what combination of open chain and closed chain exercises would efficiently improve quadriceps strength. Recent studies support an ideal rehabilitation programme before and after surgery, involving accelerated rehabilitation, in a clinic and home setting, with combined kinetic exercises. An accelerated rehabilitation protocol involving increasing muscle strength, knee ROM and proprioception along with reducing pain, inflammation and swelling can lead to better knee stability and a less complicated rehabilitation course. Despite all the recommendations, an individualised approach to each athlete, based on the resources available and personal preferences, needs to be adopted while dealing with rehabilitation of an injured anterior cruciate ligament.

Conflict of Interest

The author has not declared any conflicts of interest.

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