Review Article :

Drivers of Successful Physical Therapy Rehabilitation Program following ACL Reconstruction: A narrative review

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Abstract

The speedy and effective return to performing activity of daily living or return to sports following an ACL reconstruction is one of the key challenges for a physical therapist in a clinical setup. Literature evidences state that drivers of a successful rehabilitation program can depend on a number of variable factors where large differences in clinical and outpatient protocols have been observed with limited consensus been formed. A range of factors including the surgery timing, choice of graft and above all the rehabilitation protocol with numerous PT interventions can influence the outcome significantly. The articular cartilage, joint capsule, menisci, and ligaments are some of the connective tissues of the knee joint involved in knee injury. Among the people of younger age group 20 years to 39 years the ACL injury has the highest prevalence. An untreated ACL tear causes knee instability, making it difficult for the affected person to return to sports. The duration and exercises used in different protocols vary significantly; hence, a review was conducted to identify the most effective techniques used by therapists to treat athletes who have undergone ACL reconstruction. An extensive literature search was conducted using Cochrane, Embase, Pedro, MEDLINE, and Saudi Digital Library to identify relevant articles published in English from January 2010 to June 2022. Most athletes underwent reconstruction surgery to improve their knee function. The current review helped us to know the various treatment strategies used for the clients who are under rehabilitation following ACL reconstruction surgery. The evidences support patient education, bracing, cryotherapy, Gait training, balance re-education, joint mobilization exercises and strength training exercises. All these interventions help the athletes to regain their functional mobility and support active participation in sports. .

Keywords:

Anterior cruciate ligament, reconstruction surgery; evidence based practice; physical Therapy.

Introduction

Traumatic musculoskeletal injuries are reported as a significant health, social, and economic issue. According to WHO statistics, injuries are a serious health concern in the present day. Knee injuries affect around 244,000 persons annually, according to NHF reporting data. There are

somewhat more men than women (about 52%). Approximately 41,342 knee injuries occur annually among individuals aged 11 to 20 years old. Bednarski P[1]. According to Kerr et al.[2], the majority of injuries occurred in the lower extremities (64.4% in competition and 71.1% during practice). The percentage of injuries during competition were reported as sprains-26.0%, strains 19.2% and contusions 19.6%. The percentage of injuries during practice sessions were inflammatory conditions 15.2%, sprains 18.1% and strains 21.4%. In competition, 82.1% of head/face injuries were due to concussions, but in practice, 54.9% of head/face injuries were due to concussions. Among the ligament injuries of knee Anterior cruciate ligament injury is more common. The prevalence of Anterior cruciate ligament in Saudi Arabia was (55.4%) and it is the most highly reported ligament injuries. In United States there are 200,000 ACL injuries in which 50 percent cases require surgeries. the incidences of injury to the ligament ACL were 34 per 100,000 people in Norway. In Denmark it was 38 per 100,000 and in Sweden it is 2 per 100,000 people3. The major role of anterior cruciate ligament (ACL) is to assist the knee joint stability. The anatomical structure and attachment of the ligaments supports the joint stabilization. The ligament is made up of thick band of collagen fibers and connective tissues which stretches from the anteromedial side of the intercondylar region of the Tibial plateau to the lateral femoral condyle. The two bundles of ACL components are Anteromedial bundle and posterolateral bundle.[4-6]. The two ligaments ACL and the posterior cruciate ligament (PCL) controls excessive forward motion of tibia or excessive backward motion of the tibia with its contact with the femur during the joint movements like Knee joint flexion and extension. The another important function of ACL is also to provide rotational stability to knee during Varus stress or during valgus stress. The studies published have reported sprains and tears of the anterior cruciate ligament (ACL) are the most common injuries to knee joint. The frequency of injuries is about 100,000 to 200,000 per year in the United States. It is anticipated that between 100,000 and 200,000 new cases will be filed annually7.Knee joint injuries are most prevalent among athletes aged 15 to 25 [8]. ACL rupture is a painful injury that leads to short-term deconditioning and a long-term risk of developing osteoarthritis among athletes[9]. Numerous studies have been undertaken to determine the best efficient preventative methods and to comprehend the harm mechanism. According to published research studies the Knee injuries are caused by valgus, exter-

nal rotation, and moderate flexion[10-12]. The primary stabilizing function of the knee is carried on by the ACL. It has been documented that problem of functional knee instability is more frequent between the age group of 12 and 14 years. The reported biomechanical change in the knee following ACL injury is increased abduction loading along with low flexion angles, while there was increased flexion at Hip joint.[13] Surgical approach is much popular for ACL injury. The major indications for ACL surgery are, the patients under young age group because of their high activity level Younger patients are entitled to an ACL reconstruction earlier because of their higher activity level. Surgery is also indicated if the symptoms of instability of knee is not controlled by Physiotherapy.[14]

Auto grafts of the patellar tendon and hamstring tendon are the most prevalent types of ACL restoration surgeries [15-18]. The most often used auto grafts are quadriceps tendon, hamstring tendon, and bone-patellar tendon-bone (BPTB) (QT). When compared to BPTB, the hamstring tendon may have a slightly greater re-tear rate (2.84 versus 2.80). However, in the short- and mid-term follow-up, BPTB has a greater rate of anterior knee and kneeling pain. These changes are different in Long-term follow-up. In patients older than 35 years, allograft is a viable alternative for revisions and primary surgeries; however, the risk of re-tear is substantially higher in younger patients.[19] ACL repair graft selection is influenced by a number of variables, including age, functional requirements, and the presence of anterior knee discomfort. Allografts, more so than synthetic grafts, unquestionably require additional long-term follow-ups to support their use in response to patients' clinical, biological, and functional demands. Although the BPTB graft is still utilized today, over time the hamstrings have gained favour and are now the graft that surgeons use the most frequently. Even though the use of HT graft is still constrained by some short- and long-term complications, improvements in the techniques for fixing soft tissue have made it possible to achieve better results with hamstrings than with BPTB grafts. This is a choice that offers many benefits and lowers complications. The all-inside method is a good surgical answer in this situation to demands that are not just biological but also clinical, functional, and biomechanical.[20] The optimum graft is still debatable. The selection of the graft is influenced by the surgeon's preferences and experience, tissue availability, patient activity level, comorbidities, previous surgeries, and preferences. Compared to hamstring auto graft, patellar tendon auto graft, the most common graft source, appears to

be linked to an increased incidence of anterior knee discomfort. The ideal graft remains controversial. Graft choice depends on surgeon experience and preference, tissue availability, patient activity level, comorbidities, prior surgery, and patient preference. Patellar tendon auto graft, the most widely used graft source, appears to be associated with an increased incidence of anterior knee pain compared with hamstring auto graft. Use of hamstring auto graft is increasing. Quadriceps tendon auto graft is less popular but has shown excellent clinical results with low morbidity. Improved sterilization techniques have led to increased safety and availability of allograft, although allografts have a slower rate of incorporation than do most types of auto graft. No graft has clearly been shown to provide a faster return to play. However, in general, patellar tendon auto grafts are preferable for high-performance athletes, and hamstring auto grafts and allografts have some relative advantages for lower-demand individuals. No current indications exist for synthetic ligaments.[21]

Clinically, the most popular surgical approaches for ACL injury are auto graft like bone–patellar tendon–bone auto graft. The tendon auto graft with four-strand Semitendinosus or Gracilis tendon auto graft also stays as an important surgical technique. According to research, the clinical and functional outcomes of the latter surgical technique do not differ. Following surgery, the major goal of various rehabilitation protocols is to return athletes to their preinjury status or to the best possible level of functional activity[22]. It is mandatory to know that the methods of regaining confidence in capacity of a player in order to perform successfully was viewed as vital for motivating the participants to proceed beyond a simple return to sport and to come back to high performance which helps to attain a level of skills which might be equal to or simply more than the previous performance standards of the participants. Numerous studies have reported the relevance of emotional, cognitive and behavioral responses and its important role in the Integrated Model and indicate the significance of tackling the psychological aspects throughout the return-to-game process. Researchers demonstrated a good relationship between goal setting and adherence, which led to a positive relationship between goal setting and the rehabilitation outcome of an ACL injury. Multiple psychological therapies appeared to have facilitated the rehabilitation process. The results of few studies demonstrated that an accelerated protocol without postoperative bracing has remarkable benefits and does not result in any sort of stability issues. It was noted that the pain, swelling,

and inflammation reduction, neuromuscular control, improvement in range of motion, and strength was achieved as primary goal among these subjects. An uncomplicated rehabilitation path is facilitated by preclinical sessions, unambiguous starting times, and objective and subjective testing to monitor recovery goals. A standardized and valid technique of outcome assessment and documenting the results will also add to the scientific value of upcoming research publications. However, the recovery and return to preinjury levels of function are solely dependent on the efficacy of a specific rehabilitation procedure. With more than 265 million players, soccer game stays as the most popular sport in the world. It is also one of the sport's most frequently related associated with injuries, such as the anterior cruciate ligament (ACL). Even after successful surgery and rehabilitation, more than 25% of people with ACL injuries do not return to their previous activity levels. Within seven years of sustaining an ACL injury, 65 percent of individuals stop playing soccer. Within two years of an ACL damage, more than one-third of skeletally immature youngsters had difficulty returning to activities such as soccer. Patients have also experienced moderate to severe difficulty with walking (31%) and activities of daily life (44%), regardless of treatment. More than 22% of adolescent female soccer players underwent contralateral knee surgery or revision surgery within five years of the index knee surgery. There exist varieties of exercise protocols in ACL rehabilitation. The interpretations may also vary in ACL rehabilitation management but the important point which remains same is the achievement of outcome which every specialist and therapists wishes to reach. The important outcomes which the therapist and the team focus will be reducing swelling and minimize pain, achieving the complete joint motion, avoiding muscle atrophy, achieving flexibility, practicing normal gait pattern and the most needed outcome will be to return to the active functional life and for his work for non-athletes. Among the athletes the outcome will focus on returning to the preinjury level of fitness in terms of their muscular endurance and muscle strength. The achievement of Aerobic fitness, improvement of joint proprioception, overcoming kinesiophobia, regaining complete self-confidence stays as the mandatory goals before returning to their specialized sport activity. Achieving all these goals through systematic training will support the athlete to return to their sport activity.[23-25]The treatment strategies used by physiotherapists in clinics and hospital outpatient departments vary greatly. Participants gave a biopsychosocial and

empirical approach to the management of ACL injuries. Many research studies recommend to concentrate on resolving areas of ACL rehabilitation uncertainty or compiling results in a clinically applicable fashion[26-28]. Functional instability caused by an untreated ACL injury can cause unnecessary stress on the joint cartilage, meniscus, and ligaments surrounding the knee joint[28]. Several researchers have reported that early-onset of osteoarthritis is common among athletes with a neglected ACL injury[30-32]. Most of the athletes with ACL injuries choose ACL reconstruction surgery after receiving conservative treatment[33-35]. However, the duration and exercises used in different protocols vary significantly; hence, a review was conducted to identify the most effective techniques used by therapists to treat athletes who have undergone ACL reconstruction. It is important to understand that the active and safe return to sports by an ACL injured athlete depends on the effective rehabilitation protocol. Though the research evidences support the rehabilitation program but there is no current consensus regarding the type of rehabilitation program. Hence a review was conducted to summarize the effectiveness of various rehabilitation program following ACL reconstruction.

Materials and methods

An extensive literature search was conducted using Cochrane, Embase, Pedro, MEDLINE, and Saudi Digital Library to identify relevant articles published in English from January 2010 to June 2022. Quality assessment was performed on the titles and abstracts of the articles obtained from the databases. The literature review includes only the articles that highlights the physical therapy interventions. The articles which includes the various kinds of ACL reconstruction protocols, studies which includes randomized controlled trials, published meta-analyses, systematic reviews and cohort studies explaining the rehabilitation of patients following ACL reconstruction was included. The studies which has tested the effectiveness of hydrotherapy, effectiveness of therapeutic modalities such as TENS transcutaneous electrical nerve stimulation, ultrasound and muscle stimulation, and other complementary therapies such as reflexology was excluded in this review. Regarding estimated validity and clinical relevance, each article that was selected for inclusion received a final assessment (good, Questionable, poor). Publications of poor content were not included. Next, each included article data were retrieved regarding study question, included patients, surgical technique used, physical therapy intervention,

outcome measures, results, author's conclusion and final rehabilitation protocol. These articles were classified and Tabulated. (Table 1)

Closed and open chain exercises

Closed kinetic chain exercise are the type of exercise in which movements are performed by fixing the distal part to a stationary surface or object. In open kinetic chain the movements are performed with the distal part free to move. Many research articles have discussed the advantages and disadvantages of these exercises. Research studies that support the clinical application of open kinetic chain (OKC) and closed kinetic chain (CKC) exercises have been published earlier, although these studies have a contradictory results the benefits are still under discussion. Earlier research reported that CKC exercises are a safer and more effective method of ACL rehabilitation than OKC exercises. It is a common clinical practice to apply closed kinetic chain (CKC) type of exercises as an exercise intervention for patients who underwent Anterior cruciate ligament (ACL) reconstruction surgery as these kind of exercises produce minimal strain on the surgical graft when compared with open kinetic chain exercises (OKC). Many studies have focused on closed kinetic chain (CKC) for the past decade. However, the recent research reports have proved that there exists only a minimal difference between the strain values between the subjects who were practicing CKC and OKC exercises. The most recent research evidences support the application of both OKC and CKC exercises. These exercise protocol with combined OKC and CKC exercises will help in improving the quadriceps muscle strength and supports the athletes to return to their active sports as early as possible[36]. A systematic review conducted by Jewiss et al. [31] suggested that both OKC and CKC exercises appear to be effective in ACL rehabilitation after ACL reconstruction. In case of evaluating the patellofemoral joint pain scores and while assessing the joint laxity it is important to note that the published meta-analyses failed to prove the benefit of any one particular type of exercise. The studies showed a poor evidence in supporting the open chain exercises as a best approach for increasing knee extensor muscle strength.

There was limited to moderate evidence to prove whether there is significant difference in anterior Tibial laxity, strength, patient-reported function, or physical function with the early introduction of OKC exercises in the ACLR population, when compared to CKC exercises, at all follow-up time points. The hamstrings graft may potentially be more vulnerable

to laxity than the patellar graft, but this conclusion is based on limited evidence.[38] It was observed that Closed-kinetic-chain quadriceps exercises less likely produce overstrain to ACL grafts. In vivo studies these exercises have found to be increasing the Tibio femoral joint compressive forces and activate co contraction of hamstrings muscles and reduce the anterior Tibial displacement, which is produced during an isolated OKC quadriceps contraction.[39]The studies performed by Lobb, R et.al, it was documented that there exists weak evidence in proving the superiority of closed chain workouts for improving active knee flexion.[40] The benefit of open chain exercise was proved in the study performed by Anderson, M. J.,et.al. [41]

In a systematic review reported by Kruse etal[42] the following points were well explained, it shows that the immediate postoperative weight-bearing of surgical limb, achieving range of motion of knee from 0 degree to 90 degree of joint flexion, and resistance exercise to improve muscle strength which incorporates closed-chain exercises were reported to be safe. It is worthy to know that initiating eccentric type quadriceps muscle strengthening exercises and isokinetic hamstring muscles strengthening exercises during third week of post-operative period following ACL surgery will help in improving the muscle strength. CKC exercises have been shown to be supportive for the patients in the early postoperative period. The latest research studies have their primary focus on the safe duration to start OKC activities during early phase of ACL rehabilitation.[43] The conclusion for these studies has combined results and the effectiveness is still under discussion. This review studies wish to emphasize that our clinical approach during exercise prescription in commencement of early postoperative OKC exercises is cautious. However, the evidence to support the superiority of one over the other is insufficient.

Cryotherapy

Cryotherapy is an effective Physical therapy treatment approach to reduce pain and can be considered for analgesic use, to reduce swelling and control blood loss. Cryotherapy is also beneficial in improving the joint range of motion. The research documentation of Stålman et al has proved the effectiveness of cooling and compression in reducing the concentration of PGE2 in the synovial tissue surrounding the knee joint, following knee arthroscopy.[44] Zantop et al. [45] reported that using cryotherapy augmented with a compression device after semitendinosus ACL reconstruction is better than cryotherapy alone. Martimbianco et al. [46] concluded that using cold

compression devices significantly reduced pain scores 48 h after surgery. However, the number of studies published is insufficient to make a definitive conclusion about the effects of cryotherapy on other outcomes. Hart et al.[47] reported that the participants who performed exercises immediately after following a treatment session of cryotherapy reported more improvement in the quadriceps strength when compared to other group of subjects who received cryotherapy alone or performed exercises only. For individuals with ACL repair and chronic quadriceps arthrogenic muscle inhibition (AMI), Physical exercise performed immediately after cryotherapy improved Quadriceps muscle function and resulted in greater strength increase than in group where only exercise intervention was performed. After ACL surgery, the effective cryotherapy application to the knee joint immediately before the regulated low-intensity rehabilitation exercises has proved to facilitate the muscle strength among the individuals with the restricted quadriceps muscle function. According to Terai et al.[48], compression cryotherapy in patients who underwent semitendinosus ACL reconstruction improved their outcomes, this study included 40 patients who underwent unilateral ACL reconstruction performed by one surgeon and were followed up after 3 months. The earlier studies performed by Martimbianco et al helped us to understand the effectiveness of cryotherapy. He compared cryotherapy device with ice pack, no treatment, and placebo. Interestingly the outcome measurement for pain assessment showed a decrease in pain value at 48 hours after ACL reconstruction in cryotherapy group. Hence it was proved that Cryotherapy can be considered as a safe and effective treatment choice for post-operative pain specifically during in short-term period.

Neuromuscular training

Earlier research by Zech et al has highlighted the advantages of neuromuscular and proprioceptive training for managing various orthopedic conditions, including ACL injuries. It was reported that neuromuscular and proprioceptive training enhance the Knee function and improve the Activities of Daily living. Di Stasi and Snyder-Mackler[49] reported that perturbation training improved asymmetrical limb behavior. Furthermore, the authors revealed that non-coper women have more asymmetrical gait parameters than that in males. The study also demonstrated the beneficial effects of neuromuscular training (perturbation training) on the gait patterns of men and women with ACL deficiency. Sugimoto et al.[50] discovered four critical components (young age, long

training duration, variable training, and verbal clues) that can reduce the risk of ACL injury in knee among the athletes of female gender. Sugimoto et al.[51] also reported that female athletes who were punctual and adhered to their neuromuscular training schedule were less likely to experience an ACL injury. Ghaderi et al.[52] discovered that athletes who underwent ACL reconstruction surgery showed an improvement in joint proprioception after 8 weeks of neuromuscular training. Proprioceptive deficits persist after anterior cruciate ligament reconstruction. Following knee damage, neuromuscular training increases knee proprioception. Neuromuscular training may be advantageous for recovering injured athletes. Faggal et al [53] reported that balance training, such as single-leg stance with eyes open/closed, and performing step-ups in different directions for 8 weeks, 6 days a week for 30 min, resulted in significant improvements in joint proprioception, as

measured by knee position sense error scores. In the research study performed by Cooper et al. the benefits of proprioception training exercise, balance training exercises along with the muscle strength training program during the initial post-operative phase following ACL surgery was assessed. In this randomized controlled trial, the researchers have found that the subjects who underwent strengthening exercise gained higher scores on the Cincinnati and patient-specific functional scales when compared with the proprioceptive exercise group. The results of this study suggests that the early postoperative muscle strengthening exercises are more effective than proprioception exercise training. It is well understood that it is challenging to differentiate between muscular strengthening and proprioceptive training. Each strength-training activity has proprioceptive properties, and the vast majority of proprioceptive activities have strength-related properties. Proprioceptive training does not have a well-defined beginning point. Proprioceptive training helps in regaining confidence and minimize pain and support sport participation.

Functional bracing

Functional bracing is one of the classical approach in management of soft tissue injuries. Functional bracing when applied in a postoperative phase helps in restriction of unwanted movements and supports the development of required range of motion. It also provides resistance to medial and lateral stresses, stability to knee joint and protects from knee injuries. Nevertheless, its usefulness in ACL rehabilitation is debatable. Lowe et al.[54] reported a conflicting results regarding the role of

functional bracing following ACL reconstruction. Most of the studies included in the aforementioned reviews revealed that the patient's confidence and gait variables were improved among the subjects with bracing. However, the other studies have reported that bracing after ACL reconstruction decreases quadriceps activation and has no effect on subjective outcomes. In a randomized controlled trial involving 60 patients who underwent ACL reconstruction with Semitendinosus/Gracilis tendons, bracing had no effect on joint effusion[55].Perrone et al. [56] conducted a recent cohort case series study involving 219 adolescents who underwent ACL reconstruction and reported that functional bracing reduced the risk of reinjury .Despite the high likelihood of second ACL injury identified in this study, a braced teenage group had a significantly reduced risk of graft rupture when compared to an unbraced cohort, particularly in patients younger than 17 years old at the time of ACL surgery. Consequently, doctors treating adolescents may wish to consider functional bracing after ACL restoration in this patient population. Intriguingly, the rate of early graft tears (within 1 year of surgery) was lower in the braced group than in the unbraced group, especially among patients younger than 18 years (2% vs.12%). Naik et al. [57] reported that functional bracing had no effect on patients who underwent arthroscopic ACL reconstruction. The authors reported that a knee without bracing is a safe and cheap method for achieving an improved outcome. A prospective randomized study with a 4-year follow-up discovered no difference between patients with bracing and those without bracing[58]. A study involving 969 patients who underwent ACL reduction reported no clinical benefits from bracing.[59] The randomized control trail performed by Mayr et al compared the clinical outcome of 73 patients who underwent ACL rehabilitation. The subjects who were fitted with a water-filled soft brace were compared with those fitted with a hard brace. Both groups used braces post operatively for 6 weeks. The results of this study proved that the subjects who used soft brace had a significantly higher rating in postoperative International knee documentation committee (IKDC) subjective scores, Lysholm knee values and values of Tegner activity and significantly less effusion than the subjects who used hard brace. Whereas, the subjects with hard brace had marked deficits in extension of knee. It is interesting to note that there was no significant difference in knee joint range of motion, joint laxity in knee and thigh atrophy parameters in between the two groups. The authors concluded that the water-filled soft brace was easy-

to-use and safe and might be an efficacious alternative to the hard brace.[60]

Conventional and accelerated treatment protocols

Pualos et al. (1991) proposed a conventional postoperative regimen. After surgery, patients were usually immobilized in a cast at a 30° flexion angle for 2 weeks. The patients were allowed to ambulate with crutches (non-weight-bearing) 2 or 3 days after surgery. After 2 weeks, the cast was removed, and the patient's knee was further immobilized for 8 to 10 weeks. On the 10th week, the patient began walking with full weight-bearing. However, accelerated ACL rehabilitation necessitates the patient to walk early[61]. Accelerated ACL rehabilitation has been reported to improve scar resection [62], prevent knee extension lag [63] improve quadriceps strength, and allow for an early return to activities. According to the earlier research, eccentric exercise might be the most efficient way to regain quadriceps strength, but using the present rehabilitation techniques, a full recovery might not be possible. To optimize outcome metrics, neuromuscular training including motor learning concepts should be incorporated to strengthening training.[64-67]There were significant increases in strength and functional ability when the subjects were trained with low to moderate resistance training who underwent ACL reconstruction. It was also reported that high intensity training group showed little gain during immediate postoperative period.[68]

Walking

Quadriceps avoidance gait and unstable gait were the pre-surgery gaits utilized by the acute ACL reconstruction patients and Chronic ACL reconstruction patients, respectively.[69] Shen et al.[70] reported that 4 weeks of backward treadmill walking improved knee proprioception after ACL reconstruction. Lepley et al.[71] conducted a longitudinal study on stair walking biomechanics and reported that individuals with an ACL injury had reduced knee flexion angles and knee extension moments 6 months after injury. Shabani et al.[72] compared three groups (healthy, deficit, and ACL reconstruction) and reported that the ACL reconstruction group experienced better improvements in knee kinematics than that in the ACL deficit group. However, the study also demonstrated that ACL-reconstructed knees showed an abnormal loading pattern when compared to that in healthy knees. Similarly, Swärd et al.[73] concluded that these changes could lead to future unilateral or contralateral degenerative changes in the lower limb joints. Webster et al. [74] reported that compared to that in healthy

knees, ACL-reconstructed knees exhibited a significant increase in Tibial rotation. Hofbauer et al.[75] also suggested that these changes could be one of the factors contributing to early knee Osteoarthritis.

Return to Sport (RTS)

The player's psychological preparation is the most important part in successful return to sport SRTS. The chances of return to play are directly influenced by high sense of self efficacy, higher internal locus control and minimal level of fear. There exists minimal research evidence to support the type of training for strength, performance and functional testing during the process of RTS. According to early research, a battery of tests administered after discharge can be a useful tool for diagnosing SRTS in ACLR patients. It is documented that the major criteria for return to sports are complete flexion and extension of Knee range of motion. Reduction of pain and swelling. There should be 85 % of muscle strength compared to normal limb. Young people have a substantially higher re rupture rate than older people, so there must be a strong focus on their delayed RTS. According to recent research, the choice to delay RTS following ACLR should ideally be made at least nine months after surgery. Prevention of new or recurring injuries may be the ultimate goal of success.[76-77]

Conclusion

The effective rehabilitation approaches in the management of ACL reconstruction patients are patient education, cryotherapy, joint mobility training, muscle strength training, gait training, and balance re-education. The evidences emphasize early weight bearing and open kinetic chain (OKC) exercises. There benefit of Knee brace following ACL reconstruction has weak evidences. Proprioception and strength training were proved effective following ACL reconstruction surgery. Cryotherapy can be considered as a safe and effective treatment choice for post-operative pain specifically during the short-term period. All these effective rehabilitation techniques help the athletes to return to their sport activities as early as possible. Although many research studies exist proving the effectiveness of various exercise program for the rehabilitation of patients following ACL reconstruction, more randomized control trial studies with large sample size are needed to recommend the intensity and duration of exercise which will not only guide the Physical therapist to plan an effective protocols and also help the ACL injured patients to improve their function and enhance their sports performance.

Key points:

- The effective rehabilitation approaches for the management of anterior cruciate ligament (ACL) reconstruction patients are patient education, cryotherapy, joint mobility training, muscle strength training, gait training, and balance re-education.
- Cryotherapy can be considered as a safe and effective treatment choice for post-operative pain specifically during the short-term period.
- The research evidences support the early weight bearing and open kinetic chain (OKC) exercises.
- Joint mobility training, muscle strength training, gait training, and balance re-education exercises help to improve the function and enhance the sports performance of ACL reconstruction clients.
- Proprioceptive training helps in regaining confidence and minimize pain and support sport participation.

Table 1: Summary of Included Studies

Author	Year	Study Design	Material And Methods	Results	Method Quality*
Ana Luiza CabreraMartimbianco et al (E)	2014	Systematic review	Studies included were randomized, and quasi-randomized clinical trials were searched in essential databases. The primary outcomes measures were pain, edema, and adverse events. Ten trials were included, with a total of 573 patients.	They found a statistically significant difference in pain level between groups receiving cold compression devices compared to no cryotherapy.	+
Joseph M. Hart et al	2014	RCT	Thirty patients were included post-6 months ACLs reconstructed. The patients attended four treatment sessions for two weeks. Patients received 20 minutes of ice therapy and one hour of therapeutic exercises. The subjects were assessed on maximum voluntary quadriceps contraction.	Patients performing rehabilitation exercises immediately after ice therapy produced higher torque than those who belong to cryotherapy or exercise alone.	+
Hermann O. Mayr et al	2014	RCT	Sixty-four patients after ACL reconstruction were randomly divided into two groups. One group was treated with a brace while the other without a brace for six weeks postoperatively. Outcome measures were visual analog pain scale and radiographic evaluation.	The patient without brace had significant improvement in VAS scores, and other parameters such as joint laxity and radiographic changes were not statistically significant.	+
Maria Lindstrom et al	2015	RCT	Sixty patients participated in this study (22 women) after ACL reconstruction with semitendinosus-gracilis tendons. The patients were randomly divided into two groups, one group receiving knee bracing and another group no knee bracing. The outcome measure was joint effusion detected by computed tomography at baseline, three months, and 12 months.	There was no significant difference in knee joint effusion between groups after ACL reconstruction.	+
Dai Sugimoto et al	2016	Meta-analysis	The literature was searched through Pub Med and EBSCO. Inclusion criteria were several ACL injuries; received neuromuscular training had a control group, prospective control study design, recruited female athletes as participants.	Variety of exercises, age group, neuromuscular training, and verbal feedback as significant factors affecting ACL injury in female athletes.	+
Daniel Jewiss et al	2017	Systematic Review and Meta-Analysis	This study included randomized controlled trials of Open Kinematic Chain and Closed Kinematic Chain exercise in people who had undergone ACL reconstructive surgery. The outcome variables were Lysholm Knee Scoring Scale and Hughston Clinic Questionnaire scores.	This review included seven studies and found a non-statistical difference between Open Kinematic Chain and Closed Kinematic Chain exercise in terms of functional recovery.	+
Lowe, Walter R., et al	2017	Systematic review	PubMed and Embase databases were used to extract the studies about bracing after ACL reconstruction. In addition, a quality check of 15 included studies was performed using the Cochrane tools.	There was a contrasting conclusion about the use of bracing after ACL reconstruction. However, functional bracing is reported to improve knee joint kinematics. However, bracing is reported to decrease the quadriceps activation.	+

Author	Year	Study Design	Material And Methods	Results	Method Quality*
Amelia J.H. Arundale et al	2018	RCT	Seventy-nine athletes with 39 females participated in a randomized controlled study divided into two groups. One group received progressive strengthening, agility training, plyometrics training, while the other group received the same treatment with perturbation training on the balance board. Outcome measures were quadriceps strength, limb symmetry, range of motion, joint effusion, and pain	There was no significant improvement between the two groups. However, Male participants showed statistically significant improvement in quadriceps strength limb symmetry.	+
Zhang, Yinliang, et al	2018	RCT	Fifty-two patients who underwent ACL reconstruction participated in a study that required the patient to walk backward on the treadmill at four different inclinations. The training was carried out at a self-selected walking pace for 20 minutes for four weeks. The outcome measures were Angle Reproduction Test and Passive Motion Perception Test.	There was no significant difference in scores on the Angle Reproduction Test and Passive Motion Perception Test between 0 degrees and 5-degree inclination of the treadmill while backward walking; however, significant improvement was found when inclination was increased to 10 to 15 degrees.	±`
Faggal, Mona S et al	2019	RCT	Thirty male patients after ACL injury underwent ACL reconstruction (stump shaving and stump preservation technique). The patients participated in similar proprioceptive training. outcome measures were Lysholm scale score, dynamic balance, and proprioception (joint position sense)	There were no significant differences between the two groups in terms of improvement in strength and proprioception.	+
Jonathan A. Stone et al	2019	Prospective Cohort Study	Two hundred nineteen patients who underwent ACL reconstruction were observed for two years. The rate of re-injury or tear was compared between those who used a brace and those without a brace.	There was lower re-injury reported in braced patients than those who did not use brace after ACL reconstruction. Overall graft retear rate prevalence was 10%. Younger age group (17 years and below) and females reported the highest retear rates (18% and 13% respectively). The others factors that affected the retear were younger age, family history, and higher lateral tibial slope.	+
Arjun Ajith Naik et al	2019	Cohort study	The study included 32 patients who underwent arthroscopic ACL reconstruction. No bracing was used, and routine rehabilitation protocol was used. The patients were followed for one year. The outcome measure was Lysholm knee scores at 6 and 12 months postoperatively.	No graft failure was noted. The Lysholm knee score in the sixth month was 88 and at a year was 91.	+
Mohammad Ghaderi et al	2020	RCT	Twenty-four male athletes with ACL reconstruction in the previous 6-12 months participated in a randomized controlled trial. Each athlete performed an 8-week neuromuscular training program while the control group performed routine training. The outcome measure was knee position sense.	The neuromuscular training program resulted in a 51.3% reduction in joint position sense compared to the control group.	+
Sozaburo Terai et al	2020	RCT	Forty patients were randomly allocated into two groups. One group received cryotherapy and compression, while the other group received only cryotherapy. Each patient received cryotherapy four times a day for 30 minutes for four weeks. The outcome measures were Lysholm knee score, visual analog scale, and Short Form 36	there were better functional results among patients receiving combination treatment as compared to ice therapy alone.	+

Author	Year	Study Design	Material And Methods	Results	Method Quality*
José Manuel Pastora-Bernal	2021	Systematic review	Review was performed from the articles published in PubMed, Scopus, Web of Science, The Cochrane Library, and Physiotherapy Evidence Database (PEDro). The methodological quality, degree of recommendation, and levels of evidence were analyzed. A total of 6 studies were included.	Selected studies showed unequal results regarding pain, anxiety, fear of re-injury, function, and activities of daily living.In terms of the range of motion , anthropometric measurements, and quality of life, the results were not conclusive. Muscle activation, strength, knee laxity, time to remove external support, and neurobiological factors showed some favorable results	±`
Glattke, Kaycee E. Tummala, Sailesh V.,Chhabra, Anikar	2022	Systematic Review	A total of 824 articles from multiple search engines. Studies were evaluated using the consolidated Standards of Reporting Trials (CONSORT) criteria and National Institutes of Health (NIH) Study Quality Assessment Tools.	When utilized in the perioperative period, cryotherapy is a powerful painkiller. High-intensity plyometric training is ineffective, and the early adoption of open kinetic chain activities may improve ACL reconstructive outcomes. To recover muscle function, electromyography biofeedback may be helpful.	+

*Final judgment methodological quality of included RCT or review is good (+), questionable (±) or poor (-)

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