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Pre and post-operative rehabilitation of anterior cruciate ligament reconstruction in young athletes

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Abstract
Background: Anterior Cruciate Ligament (ACL) injury and reconstruction surgeries are common among young athletes, who are frequently involved in sports activities. Research suggests that ACL injuries among sportsmen have the longest disability time and the most expensive to treat. The pre and post-operative rehabilitation exercise of ACL ruptures continues to be controversial.
Objectives: The aim of this review is to systematically review the current evidence of the exercise therapy for pre and post-operative stages, and to identify uncovered issues for future investigations.
Methods: Three databases: Medline, Pedro, and Cinahl were searched for all published literature from 1975 to 2017 using key words such as, "ACL reconstruction" and other synonyms. 140 citations were identified, based on the predefined inclusion/exclusion criteria, and further analyzed.
Results: It is necessary that rehabilitation of the ACL injury begins immediately after the first office evaluation. Sufferers who plan an ACL reconstructive surgery should have a discussion with their therapists before the surgery about pre-operative treatment options. Several effective exercises were identified and presented in this paper.
Conclusion: A structured pre and post-operative rehabilitation program can significantly decrease the incidence of joint stiffness and other complications in injured knees, and help the athletes to return to play on time. The authors presented a validated rehabilitation protocol, which can significantly decrease post-operative complications if applied properly. Finally, this study identified several gaps in literature regarding the effectiveness of physiotherapy modalities like, electrotherapeutic interventions, in the management of such injuries.

Keywords: ACL injury, ACL reconstruction, rehabilitation of anterior cruciate ligament

Introduction
Over two million of anterior cruciate ligament (ACL) injuries happen worldwide annually. [1] Statistics suggest that 81-85 ACL injuries take place in every 100, 000 citizens in a society. [2, 3] ACL tears is the most common, complete ligamentous accidental injuries that occur in the leg joints. In the United States, ACL injuries occur at least once in 3, 500 individuals every year, [1] and approximately 125, 000 to 200, 000 ACL reconstructions are performed annually. ACL accidents and reconstruction surgeries are common among young athletes (under 25 years old), who are frequently involved in sports activities. [4] Research suggests that ACL injuries among sportsmen have the longest disability time and the most expensive to treat. [5] The treatment of ACL ruptures continues to be controversial. [6] A few authors recommend conservative treatment, while others consider conservative strategies are insufficient. [7–10] Furthermore, controversies exist as to whether surgical treatment should be performed acutely, [11] or only when anterior laxity becomes an issue. Strength training programs are believed to be indispensable for patients with ACL ruptures. Apart from this debate and controversy, there is an agreement among authors that physical rehabilitation is a key element before and after the surgical intervention. However, the aim of this review is to systematically review the current evidence of the exercise therapy for pre and post-operative stages, and to identify uncovered issues for future investigations.

Anatomy and Biomechanics of the Anterior Cruciate Ligament
The ACL is a band-like composition of dense connective tissue that extends from the femur to the tibia.

It takes its origin from the posteromedial part of lateral femoral condyle and descends downward, medially and anteriorly to insert into the inter-condyloid eminence of the tibia. [12] The ACL is lateral to the midline and occupies the superior 66% of the extensive aspect of the notch by using an anterior view of the flexed knee joint. The size of the bony attachment can vary via 11 to 24mm. [12, 13] Its length ranges from 22 to 41 mm (mean, 32 mm) and its thickness from 7 to 10 mm. [14]

The ACL plays a crucial role in joint stability. It provides about 85% of total resistance force of anterior translation of the tibia. [15] It also plays an important role in limiting excessive tibial rotation both medially and laterally. ACL also plays a minor role in resisting extension and hyperextension of knee joint, [16] especially underweight bearing conditions. [17, 18] The ACL receives nerve fibers from the posterior articular branches from the tibial nerve. [19] Hyperextension is controlled simply by both collateral ligaments, the two cruciate ligaments, both menisci, the posterior aspect of the articular capsule, the oblique popliteal ligament, and the structures of the femoral condyles. Hyperflexion is controlled by both cruciate structures, both menisci, the femoral attachment of the posterior facet of the capsule, the femoral attachment of both mind of the gastrocnemius muscle, as well as the bone structure of the condyles of the femur and the shin. [20]

Effects of muscle stabilization

Individuals with an unstable knee due to an ACL rupture rely greatly on muscle function throughout the joint to maintain dynamic balance during functional activity. It is really uncertain which muscles perform the decisive role in functional stability, or more precisely, which aspect of muscle function is most critical. [21] Disagreement exists over if the quadriceps or the hamstring muscle tissue are more strongly related to practical stability. Some investigators consider that hamstring muscle activity relates more to function overall performance in ACL deficient topics because of their action in avoiding anterior tibia shear. [22] Hamstring power was significantly correlated to functional ability scores. Nevertheless, Goldfuss *et al.* has claimed that quadriceps muscle is strongly related to useful stability as it increases inside stiffness of the knee by 48%. [23] In addition, Wilk ainsi que *et al.* reported a significant positive relationship between quadriceps strength and functional testing, but not among hamstring strength and function. [24] Creating specific muscular contribution and relationships to functional balance is currently important for considering the graft source for ACL reconstructions and for influencing rehabilitation applications. It is known that the quadriceps more strength compared to the hamstrings following injury and surgery, especially when the patellar tendon is used as a graft source [25].

Rehabilitation

Early rehabilitation of post-operative ACL reconstruction focuses on protection from the new ligament with obstructing of full extension, [26–28]-[29] This approach led to numerous post-operative complications, including stiffness, some weakness, and patellofemoral problems. [30–32] Rehabilitation after the ACL reconstructive surgery is essential for leg functional outcomes. [33, 34] Since clinical methods in the management of ACL injury are varied, there is absolutely no standard agreement on the best treatment algorithm for individuals with ACL reconstruction. [35, 36] The relationship between the biomechanical dose of rehabilitation exercises administered after surgery, as well as the healing response of the graft and knee is not really well understood. [36] Enhancement in the neuromuscular control of the knees following ACL injury, or perhaps reconstruction, may lead to better results in terms of returning back to practical activities and a reduced risk of recurrent injury. [37] Two main goals of ACL rehabilitation: the enhancement of useful ability, and the realization of greater participation in work, or perhaps sport activities. These desired goals are only achieved by intensive treatment to improve strength, proprioception and reaction time, and by practice in daily activities to increase involvement. Following an ACL injury, problems occur in strength,[38] Proprioception, [38, 39] and gait patterns. [21] In fact, strength and proprioceptive alterations occur in both injured and uninjured leg. [40, 41] The primary impairment with an ACL deficient leg is instability. This is demonstrated by episodes of 'giving way', which can lead to additional joint damage and eventually, long term degenerative changes. [42] Research has demonstrated that therapy provided pre-operatively is effective in increasing strength and stability which may limit the number the episodes of 'giving way' and decrease the incidence of re-injury in the ACL lacking knee. [43] The main goals of a rehabilitation program prior to surgery consist of full range of motion corresponding to the opposite knee, minimal joint swelling, adequate strength and neuromuscular control, and an optimistic state of mind. [44] Most of these factors facilitate optimal post-operative recovery. It is important to maintain the greatest level of strength and function feasible in the unaffected leg since it will be used for comparison to evaluate the progress of the reconstructed knee, in the later phases of rehabilitation. [45, 46]

Methods

Three databases: Medline, Pedro, and Cinahl were comprehensively searched for all published literature from 1975 to 2017 using the following key words: anterior cruciate ligament reconstruction, ACL reconstruction, ACL reconstruction rehabilitation, and ACL reconstruction results. Also, manual searches of the following journals were performed: *The American Journal of Sports Medicine*; *Arthroscopy*; *The Journal of Bone and Joint Surgery. The Knee*; *Clinical Orthopedics and Related Research*; and *Knee Surgery, Sports Traumatology, Arthroscopy*.

All English peer reviewed articles were included for further analysis. Exclusion criteria were revision ACL reconstruction; dislocated knees; major concomitant procedures such as high tibial osteotomy, meniscus allograft, or other knee ligament reconstructions; follow-up of less than 12 months; the population of study is not athletes; and other types of articles such as reviews, case reports, abstracts, and technical notes. Figure (1) illustrate the search process.

Results and Discussion

It is necessary that rehabilitation of the ACL injury begins immediately after the first office evaluation. Physical counselors follow patients closely and communicate with the surgeon about the patient's mental and physical preparation for surgery, since these factors are equally important in the successful reconstruction of the ACL. [47, 48] Sufferers who plan an ACL reconstructive surgery should have a discussion with their therapists before the surgery about pre-operative treatment and their active role in this important time. Before surgery is considered, sufferers are expected to meet a series of circumstances, including completely normal Range of Motion (ROM) comparable to that of the opposite knee, lowered knee effusion, normal running, and good leg control. To achieve those ends, several exercises are recommended together with a Cryo/Cuff (or ice) to reduce swelling. The exercise include:

towel stretching exercises; heel props exercises; position extension habit; wall glide and heel slide exercises; and gait training. Obtaining full ROM before surgical procedure reduces the likelihood of motion challenges post-operatively, so surgery is definitely not performed until a full extension of the injured knee equal to the non-involved knee is achieved, and is also able to sit on his or her pumps [8].

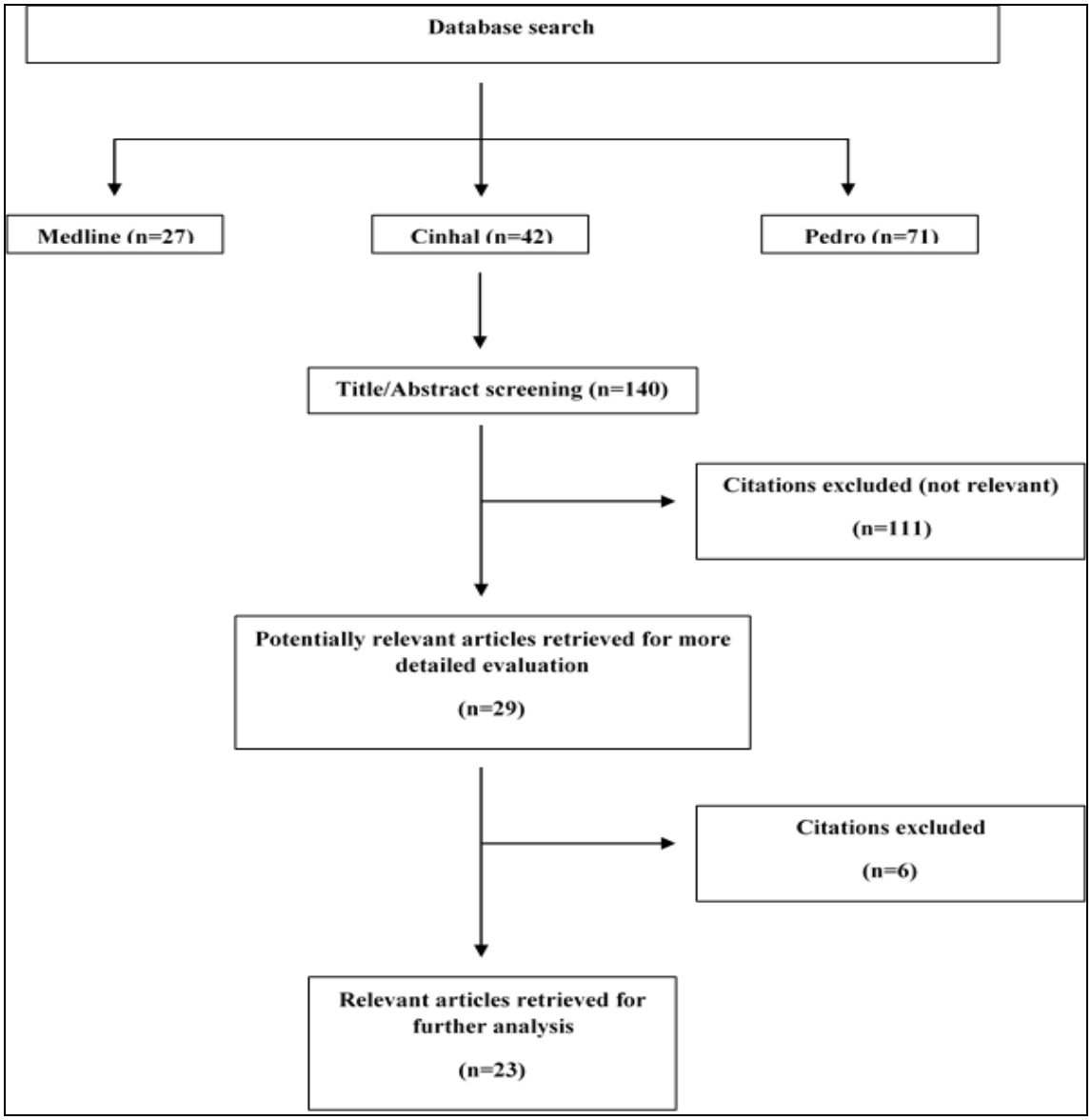


Fig 1: Illustration of databases search strategy

Perioperative Rehabilitation Phases

Table 1: Perioperative rehabilitation phases

Phase	Goals	Specific exercises
Preoperative	Getting normal physiology Heel stage sets, towel stretches, prone hangs; gait and stance and motion	Back heel props, towel stretches, susceptible hangs; gait and position training; heel slides, flexion hangs, wall slides
Instantly postoperative phase: through first days	Total extension, 115° of flexion; limited effusion; unassisted lower-leg lifts and ambulation with normal gait	CPM flexion, heel slides, right leg raises, heel stage sets, towel stretch; cold/compression gadget continually
More advanced phase: weeks 2-4	Total extension, 120° of flexion progressing to full flexion; improving effusion	Back heel props, towel stretches, Top notch Seat, correct stance and walking, heel slides, flexion hangs; step low level; cold/compression device
Advanced is strengthening phase	Complete motion and symmetrical power in both knees.	Advancing from above to step package at higher level, leg press, straight-line running; StairMaster, an ellpitcal machine, progression to sports particular exercise; cold/compression as required; knee motion monitored regularly: adjust strengthening and actions to ensure full motion is usually maintained
Return to competition	Symmetrical normal knees; full competition	Sports-specific exercise, functional progression, go back to competition

Perioperative rehabilitation figures (1to 4)

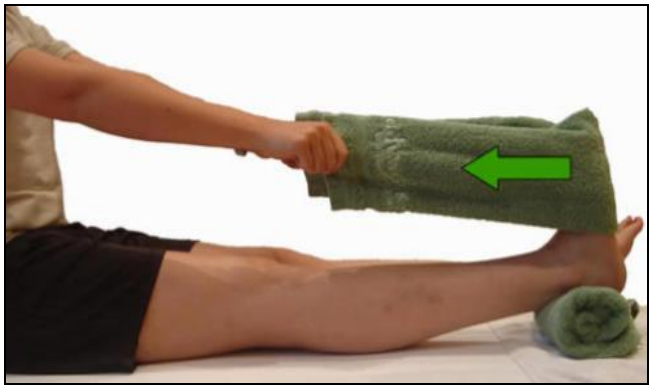


Fig 1: Towel stretch for knee extension. The towel is used to lift the heel of the affected lower extremity to end-range hyperextension by pulling the end of the towel upward toward the shoulder

Fig 2: Achieving full symmetrical flexion means the patient should be able to kneel and sit back on heels comfortably

Fig 3: Cryo/Cuff provides both compression and cold therapy to reduce swelling. This modality used in combination with elevation in the continuous passive motion machine can effectively reduce any intraarticular effusion or hemarthrosis

Fig 4: The Elite Seat device allows the patient to recline completely, which relaxes the hamstrings. The patient uses a pulley control to increase the mechanical force for knee extension

Many surgeons prefer early postoperative full weight bearing with an average of 3. 8 weeks of postoperative bracing. Physical therapy commonly ranged from 1-4 months with return to sport at 6-7 months, generally with a practical brace. [49] A summary of rehabilitation phases and exercises is presented in the following tables according to their citation frequency in literature. [50–59]

Table 2: Accelerated Rehabilitation after Cruciate Ligament Reconstruction (Table 2)

Date after surgery	Treatment
2-3 days	CPM Passive ROM exercise intended for terminal extension and 80 flexion Wightbearing as suffered
3-4 days 7-10 days	Discharge from hospital RANGE OF MOTION terminal extension Prone hugs and towel extensions Wall structure slides, heel slides, energetic assisted flexion Strengthening leg bends, step ups leg raises, partial to full weight bearing
2-3 weeks	ROM terminal extension to 110 unilateral knee bends, step ups, calf increases Weight room activities '" leg press, quarter profession and calf raises inside the squat rack Bicycling, going swimming
5-6 weeks	ROM terminal extension to 130 Isokinetic evaluation with 20 degree Block in 180 and 240 deg-sec If greater than 70%, begin lateral shufles, cariocas, and jumping rope continued weghit room activities Continue riding a bicycle and swimming
12 weeks	Full Range of Motion Isokinetic evaluation at sixty, 180, and 240 deg-sec Kt 1000 Increased speed workouts
16 weeks	Isokinetic evaluation, kt 1000 Increased agility exercises

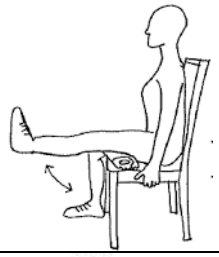
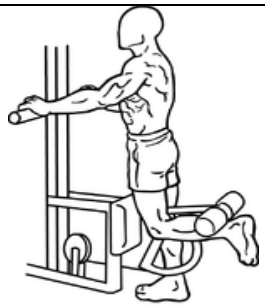
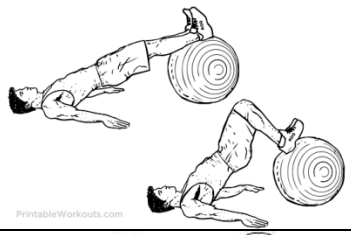
Table 3: Conventional rehabilitation program after Cruciate Ligament Reconstruction (table 3)

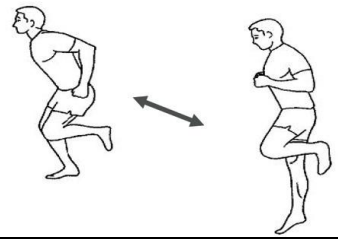
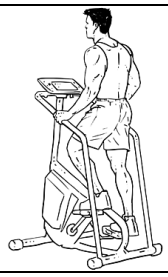
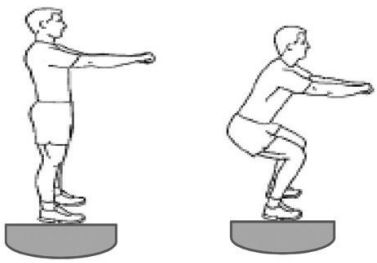
Date after surgery	Treatment
2-3 days	CPM Passive ROM 0-60 Incomplete weight bearing with crutches and splint
3days 1-2 weeks	Discharge coming from hospital ROM 0-90 Wall structure slides, heel slides, right leg raise Step ups, calf raises partial excess weight bearing
3-4 weeks	ROM O-100 Susceptible hang for terminal expansion Full weight bearing Fragmentario knee bends, step- ups, calf raise partial profession, biking
5-6 weeks	ROM- terminal file format to 130 Isokinetic analysis with 2o block in 180 and 240 deg-sec Partial squats, leg press, biking with moderate level of resistance, jump rope
4 months	Full ROM Isokinetic evaluation at 60, 18, 240deg-sec Continue with conditioning, biking, swimming functional development if strength 70%
6 months	Isokinetic evaluation, kt- 1000 Boost agility

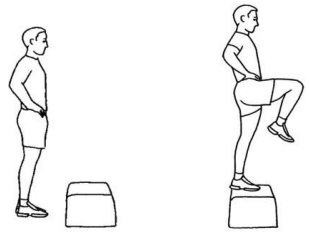
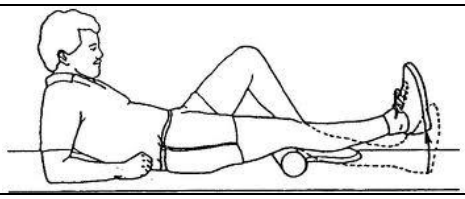
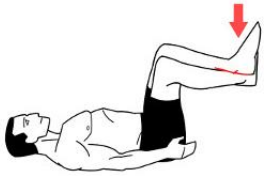
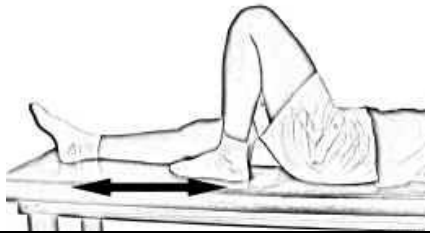
Table 4: Post-Operative Rehabilitation Phases

Phase of Rehabilitation	Approximate Time (weeks)
Maximum protection Early healing period Controlled motion period	12 4 to 6 6 to 8
Moderate protection Crutch-weaning period Walking period	12 4 8
Minimum protection Protected activity period Light activity period	12 6 6
Return to activity Advanced rehabilitation period Running period	12 6 6 to 12
Activity and maintenance Return to sports period Maintenance period	12 - -

Table 5: The exercises program that are commonly cited in literature (table 5)

Exercise	**Description**	**Sets by Number of Repetitions**	**Figures**
Single-limb knee Extension	Start in 90° knee flexion	4 × 6 (+2)	
Squats	Squat slowly down to 90° knee flexion, stop, lift quickly up again	3 × 8 (+2)	
Leg curl	Lift quickly up, stop, and then slowly down to full extension	3 × 8 (+2)	
Hamstring on the ball	One foot on top of the ball, lift back and pelvis up, pull ball towards you	3 × 6	
Single-leg hop	Hop up on step, stop, continue down and directly 1 hop forward with a soft controlled landing	1 × 15	

Sideways single-leg hop	Start on 1 side of a board. Hop quickly sideways and stop after 3 hops. Continue and stop 5 times	3 × 15	
Skating	Start on 1 leg, hop sideways, perform a soft, deep and steady landing on 1 leg, hop back to the other side	2 × 20	
Treadmill	Continuous warm-up at your preferred speed	10 min	
Stationary cycle	Continuous warm-up at your preferred resistance	10 min	
Elliptical trainer	Continuous warm-up at your preferred resistance 10 min Single-	10 min	
Single-limb squat	Maintain knee-over-toe position	3 × 8	
Squat on BOSU	Maintain knee alignment and core stability. Squat quickly down and up	2 × 20	

Step-up	Maintain knee-over-toe position	2 × 10	
Single-limb leg press	Start in 90° knee flexion	3 × 6	
Towel extend	Push your knee against the towel	3 × 20	
Prone hangs	By pushing up with the unoperated leg.	2 × 20	
Wall slide	Slide your foot up and down	2 × 20	
Heel slides	Slide your foot until full flexion	2 × 20	
Swimming		30mints	
Jump rope		3 × 10	

Return to Sport

Usually, athletes are allowed to run, golf, or to do other non-pivoting sports in 5 months

depending on how their knee is advancing and any other associated accidental injuries. Full return to contact sports activities is allowed at six months based on conditioning of his/her leg [60]. All exercises should be performed at each workout. Two to Three series in every session. Training sessions minimal two, maximum 4 times per week. Development from increasing lots around the strength exercises as well as for larger steps, longer/higher leaps, motion in several directions plus more shaky surfaces for the neuromuscular and plyometric exercises. [61, 62]

Conclusion

Anterior cruciate ligament injury is one of the most common injuries among young athletes in both developed and poor societies. This injury is also considered a big concern among policy makers, sport-related administrations, and athletes themselves because of the scary negative consequences that may a raise, if this injury hadn't have a proper rehabilitation both in pre and post-operative stages. In literature, there is little consensus and much confusion regarding the rehabilitation process, but the good news is that most authors agree that exercise is the key element for successful rehabilitation and return to sport sooner. According to the findings of this review, delaying the reconstruction by at least 3 weeks resulted in a significant increases the incidence of arthrofibrosis, which is a complication of injury that causes painful restriction of knee joint range of motion. An accelerated post-operative rehabilitation program can significantly decrease the incidence of this pathology in knees that are reconstructed sooner than 3 weeks after injury. The authors presented an accelerated rehabilitation protocol, which has been proven by numerus studies that it can significantly decrease post-operative complications if applied properly. Finally, this study identified several gaps in literature regarding the effectiveness of physiotherapy modalities like, electrotherapeutic interventions, in the management of such injuries.

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